Canada's Oil and Gas in a Low-Carbon Economy

Report of the Standing Senate Committee on Energy, the Environment and Natural Resources

The Honourable Rosa Galvez, Chair
The Honourable Michael L. MacDonald, Deputy Chair

May 2018

Senate | Sénat
Canada

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MEMBERS OF THE COMMITTEE

The Honourable Rosa Galvez, *Chair*

The Honourable Michael L. MacDonald, *Deputy Chair*

The Honourable Senators:

Jane Cordy
Renée Dupuis
Paul J. Massicotte
Percy Mockler
Richard Neufeld
Dennis Glen Patterson
David Richards
Judith Seidman
Howard Wetston

Ex officio members:

The Honourable Peter Harder, P.C. (or Diane Bellemare), or (Grant Mitchell)
The Honourable Larry W. Smith (or Yonah Martin)
The Honourable Yuen Pau Woo (or Raymonde Saint-Germain)
The Honourable Joseph A. Day (or Terry M. Mercer)

The Committee would like to recognize the following Senators who are no longer serving members of the committee whose contribution to the study was invaluable:

The Honourable Senators: Douglas Black, Tony Dean, Joan Fraser (retired), Diane F. Griffin, Daniel Lang (retired), Elaine McCoy, Grant Mitchell and Pierrette Ringuette.

Other Senators who have participated from time to time in the study:

The Honourable Senators: Salma Ataullahjan, Diane Bellemare, Lynn Beyak, Joseph A. Day, Michael Duffy, Nicole Eaton, Tobias C. Enverga (deceased), Stephen Greene, Janis Johnson (retired), Yonah Martin, Paul E. McIntyre, Don Meredith (retired), Ratna Omidvar, Nancy Greene Raine, Bob Runciman (retired) and Scott Tannas.

Parliamentry Information and Research Service, Library of Parliament:

Sam Banks, Marc LeBlanc and Jesse Good, Analysts

Senate Committees Directorate:

Maxime Fortin, Committee Clerk
Brigitte Martineau, Administrative Assistant

ORDER OF REFERENCE

Extract from the *Journals of the Senate*, Thursday, March 10, 2016:

The Honourable Senator Neufeld moved, seconded by the Honourable Senator Frum:

That the Standing Senate Committee on Energy, the Environment and Natural Resources be authorized to examine and report on the effects of transitioning to a low carbon economy, as required to meet the Government of Canada's announced targets for greenhouse gas emission reductions. Recognizing the role of energy production, distribution and consumption in Canada, the committee shall be authorized to:

(*a*)identify and report on the impact transitioning to a low carbon economy will have on energy end users, including Canadian households and businesses;

(*b*)identify and report on the most viable way the following sectors — electricity, oil and gas, transportation, buildings and trade-exposed energy intensive industries — can contribute to a low carbon economy in meeting Canada's emission targets;

(*c*)examine and report on cross-sector issues and undertake case studies, if necessary, on specific programs or initiatives aimed at reducing greenhouse gas emissions;

(*d*)identify areas of concern and make any necessary recommendations to the federal government that will help achieve greenhouse gas emission targets in a manner that is sustainable, affordable, efficient, equitable and achievable.

That the committee submit interim reports on identified sectors, cross-sector issues and case studies and submit its final report no later than September 30, 2017, and that the committee retain all powers necessary to publicize its findings until 180 days after the tabling of the final report.

After debate,

The question being put on the motion, it was adopted.

Charles Robert
Clerk of the Senate

Extract from the *Journals of the Senate*, Tuesday, September 26, 2017:

The Honourable Senator Neufeld moved, seconded by the Honourable Senator Martin:

That, notwithstanding the order of the Senate adopted on Thursday, March 10, 2016, the date for the final report of the Standing Senate Committee on Energy, the Environment and Natural Resources in relation to its study on the transition to a low carbon economy be extended from September 30, 2017 to June 30, 2018.

The question being put on the motion, it was adopted.

Nicole Proulx
Clerk of the Senate

ACRONYMS

BBC	Bitumen beyond combustion
bbl	Barrel
Bcf/d	Billion cubic feet per day
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalents
ERA	Emissions Reduction Alberta
GDP	Gross domestic product
GHG	Greenhouse gas
GJ	Gigajoule
IEA	International Energy Agency
kg CO_2e/bbl	Kilograms of carbon dioxide equivalent per barrel of oil
kg CO_2e/boe	Kilograms of carbon dioxide equivalent per barrel of oil equivalent
kt	Kilotonne
LNG	Liquefied natural gas
MMb/d	Million barrels of oil per day
Mt CO_2e	Megatonne (1 million tonnes) of carbon dioxide equivalent
Mtoe	Millions of tons of oil equivalent
NEB	National Energy Board
NGLs	Natural gas liquids
NRCan	Natural Resources Canada
RD&D	Research, development and demonstration
RPPs	Refined petroleum products
SAGD	Steam-assisted gravity drainage
SMEs	Small- and medium-sized technology companies
UNFCCC	United Nations Framework Convention on Climate Change

EXECUTIVE SUMMARY

The Standing Senate Committee on Energy, the Environment and Natural Resources is studying what it will cost ordinary Canadians and businesses to meet Canada's greenhouse gas (GHG) emission reduction targets. It is examining the effects Canada's GHG reduction targets will have on five sectors of the Canadian economy: electricity, transportation, oil and gas, buildings and emission-intensive and trade-exposed industries.

The oil and gas sector is the subject of the committee's current study of the low carbon transition and it represents the committee's fourth interim report. The committee released its first interim report on the electricity sector in March 2017, its second interim report on transportation in June 2017 and its third interim report on emission-intensive and trade-exposed industries in April 2018.

In a final report, the committee will make recommendations to the federal government that will help achieve Canada's emission reduction commitments in a manner that is sustainable, affordable, efficient, equitable and achievable.

As Canada acts to reduce its GHG under its Paris Agreement commitments, what role will the domestic oil and gas industry play in the shift to a low-carbon economy? Canada has a large, resource-based economy and the oil and gas industry is an important part of it. The current structure of Canada's oil and gas industry can be traced back to the country's rapid post-World War II expansion in oil and gas production and subsequent development and application of new extraction technologies.

In 2015, the industry directly and indirectly employed over seven hundred thousand Canadians and contributed $142 billion to the country's gross domestic product (GDP).[1] Yet the industry is also responsible for the largest share of Canada's GHG emissions (26%) and is the main driver of recent and forecasted domestic GHG emission growth.[2]

Over the long term, future world demand for oil and gas will be contingent on the speed and scope of collective actions taken by countries to address climate change. If the global community achieves its Paris Agreement targets then overall demand for oil and gas commodities will decrease. In light of this, Canada's oil and gas industry faces challenges to cost-effectively reduce emissions while retaining and competing for market share in a carbon-constrained world.

The majority of Canada's oil and gas reserves are unconventional resources, such as oil sands or shale gas, that are relatively high-cost to produce and which have comparatively high emission intensity compared to conventional oil and gas production in Canada. Despite this, the committee heard optimism that clean technology and innovation could substantially improve the emissions profile of Canada's oil and gas sector. However, given the scale of the emission reduction challenge, accelerated breakthroughs in transformative technologies will be needed.

Federal, provincial and territorial governments are considering a range of policy tools to achieve emission reductions in the oil and gas sector, including carbon pricing. The federal government committed to reducing methane emissions in the sector through regulations. The challenge will be to balance the need to maintain competiveness and encourage investment in the industry while advancing increasingly stringent emission reduction requirements.

Upstream oil and gas industries are those involved in extraction, production, processing activities. Petroleum refining is not included in this report because it is included in the committee's third interim report entitled *Decarbonizing Heavy Industry: the Low-Carbon Transition of Canada's Emission-Intensive and Trade-Exposed Industries*.

ADDRESSING CLIMATE CHANGE

Climate change is a destabilizing threat to global health and security that could define the current century more than any other. The effects of climate change are already observable. For example, since the 1960s, the earth's ocean heat content increased at all depths by approximately 0.7°C and global sea level has risen up to 21 centimetres.[3] Globally, 16 of the 17 warmest years since the late 1800s have occurred in the period from 2001 to 2016.[4] If temperatures continue to rise unabated, the world risks substantial species extinction, significant global and regional food insecurity, increased risks of violent conflict and large population displacements.[5]

Canada is seeing the effects of climate change. Temperatures in Canada have risen at approximately double the global rate.[6] The country's northern regions are particularly vulnerable to accelerated losses of sea ice and permafrost affecting wildlife and ecosystems. Climate change is also jeopardizing northern infrastructure including roads, buildings, communication towers and other facilities. According to the Final Report of the Federal Provincial and Territorial Working Group on Adaption and Climate Resilience all regions will be affected:

> *Climate change is impacting the severity and frequency of extreme events, including the likelihood of flooding, droughts, storm surges, high winds, and heat waves. Changes in temperature and precipitation patterns have made the wildfire season longer, while drought- and pest-stressed forests, woodlots, and rangelands are increasing the severity of wildland fires. Sea level rise is increasing the frequency and height of storm surges, causing flooding in higher, previously unaffected areas and more frequent flooding in low lying areas.*[7]

The financial costs of these climate occurrences are mounting. According to the

Insurance Bureau of Canada, expected losses due to severe weather currently exceeds $1 billion annually in Canada whereas in the 1980s and 1990s these costs averaged at below $300 million a year.[8]

While climate change is a pressing problem, many countries, including Canada, have postponed difficult decisions needed to curb GHG emissions. The 2017 Fall Report of the Commissioner of the Environment and Sustainable Development reported that Canada has failed to achieve every emission target it has set since 1992. These include reducing emissions to 1990 levels by 2000 (the Rio Earth Summit); 6% below 1990 levels by 2012 (Kyoto Protocol); and 17% below 2005 levels by 2020 (Copenhagen Accord). Reducing GHG emissions is a complex problem but inaction in addressing climate change will have severe consequences on this and future generations.

Considering that everyone shares the atmosphere, climate change solutions require an ambitious level of global co-operation. On 12 December 2015 in Paris, Canada and 194 other countries party to the United Nations Framework Convention on Climate Change (UNFCCC) reached an agreement (Paris Agreement) to limit rising global average temperatures to less than 2°C above pre-industrial levels, and aim to limit that increase of no less than 1.5°C.[9] This was a pivotal moment in the effort to address climate change, as both developed and developing countries were part of the agreement, representing nearly all of the world's anthropogenic emissions. In June 2017, the United States, a major GHG emitter, submitted a formal notice of withdrawal from the agreement. However, many U.S. states, municipalities, institutions and companies have maintained their commitment to reduce emissions to achieve Paris Agreement objectives.[10]

Climate change is occurring as global energy demand is growing. The International Energy Agency's 2017 World Energy Outlook estimates that global energy use will increase by nearly 28% by 2040 due to increased demand from emerging economies.[11] Of that increase, more than half (51%) comes from the demand for oil, natural gas and coal. Also, current low prices for oil are challenging policy efforts to switch to cleaner fuels.

Canada's Emission Commitment

GHGs are associated with almost every activity, product and service and are supported by long-lived capital infrastructure.[12] Addressing climate change will require a rapid and substantial retooling of energy systems that have supported economies for nearly a century. It is an energy transition chiefly driven by public policy through regulation, taxes and/or incentives and it will likely require a change in lifestyle and energy/resource consumption habits. It will not be cost-free, meaning that it will likely require higher demands on public revenues, result in higher energy prices, impact households and businesses, and will probably strand existing productive capital assets that support fossil fuel energy systems.[13]

In accordance with its contribution to the Paris Agreement under the UNFCCC, Canada committed to reduce its emissions by 30% below 2005 levels by 2030. This target is a minimum target. Further reductions will be needed to reach the Paris Agreement's goals. This envisions an 80% reduction in

emissions from 2005 levels by the second half of the century.[14]

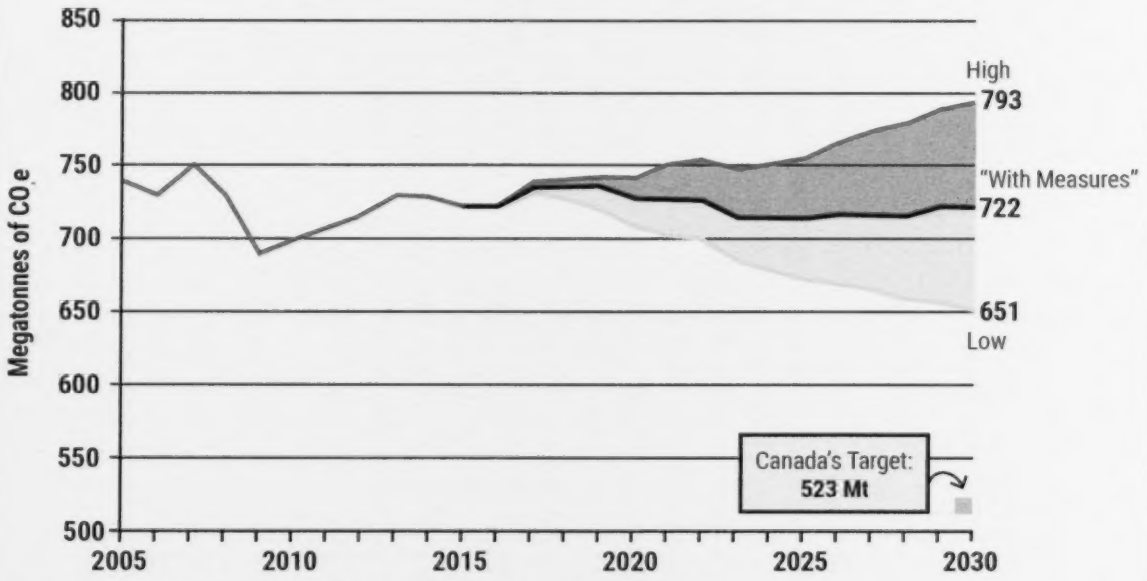
In the wake of the Paris Agreement, federal, provincial and territorial governments have committed to working together to reduce emissions. In December 2016, Canada's First Ministers released the Pan-Canadian Framework on Clean Growth and Climate Change, which was adopted by all Canadian provinces and territories with the exception of Saskatchewan. The Framework builds on previously announced initiatives, such as a national benchmark price on carbon emissions and an acceleration of the phase-out of traditional coal-fired electricity units.

The projections from Environment and Climate Change Canada illustrated in Figure 1 reflect forecasts for gross domestic product (GDP) and oil and gas prices and production. They also include "actions taken by governments, consumers and businesses put in place over the last two years, up to September 2017. This scenario does not account for all measures of the Pan-Canadian Framework as a number of them are still under development."[15] These actions are referred to by the Government of Canada as the "with measures" scenario.

The projections do not include additional policies and measures under development but have not yet been fully implemented. Some of these were announced as part of the Pan Canadian Framework such as pan-Canadian carbon pricing or federal regulations to reduce methane emissions in the oil and gas sector (methane is a GHG that is 25 times more potent in trapping heat in the atmosphere than carbon dioxide).

The projections show a range of GHG emission level outcomes based on the uncertainty inherent in modelling climate policy and other macroeconomic conditions that are beyond the control of government. The reference case scenario, which assumes business-as-usual oil and gas prices and GDP growth is contrasted with two scenarios: one assuming high oil and gas prices and GDP growth and another with assuming low oil and gas prices and GDP growth.

Figure 1 – Canada's Domestic Emissions Projections (Mt CO_2e): Low, "With Measures" and High Scenarios



Note: In 1990, Canada's GHG emissions totalled 611 Mt CO_2e.

Mt CO_2e = megatonne (1 million tonnes) of carbon dioxide equivalents. Different greenhouse gases have different radiative forcing potentials depending on their lifetimes in the atmosphere and how efficiently they contribute to the greenhouse effect. The global warming potential of the different greenhouse gases can be expressed in relative terms to those of carbon dioxide, known as carbon dioxide equivalents, or CO_2e.

Source: Environment and Climate Change Canada, *Canada's Seventh National Communication on Climate Change and Third Biennial Report—Actions to meet commitments under the United Nations Framework Convention on Climate Change,* page 155.

Legend: Emissions projections in three scenarios:

1. High oil and gas prices and high GDP growth – blue line
2. Business-as-usual oil and gas prices and GDP growth – black line
3. Low oil and gas prices and low GDP growth – yellow line

Fuel Price Assumptions	High	With Measures	Low
Annual GDP Growth Rate (2015-2030) %	2.5	1.7	1.0
Crude Oil Price (West Texas Intermediate) 2014 US$/bbl	116	77	37
Heavy Oil (Western Canadian Select) 2014 US$/bbl	90	56	21
Natural Gas (Henry Hub) 2014 US$/GJ	4.67	3.77	2.86

These emissions projections incorporate oil and gas price forecasts set out in the National Energy Board's energy outlook, *Canada's Energy Future 2016: Update – Energy Supply and Demand Projections to 2040*, published in October 2016.

Figure 2 provides a breakdown of Canadian emissions by economic sector. In 2015, the upstream oil and gas and transportation sectors each accounted for nearly a quarter of total emissions in Canada. Emissions from buildings was 12%, followed by electricity generation at 11% and agriculture at 10%. Emission-intensive and trade-exposed industries consisting of steel, aluminium, cement, petrochemical, pulp and paper, fertilizer and mining production totalled 10% of total emissions in Canada. Petroleum refining, which is also an EITE industry, was of 3% total emissions. Table 1 provides the breakdown for different years including projections for 2020 and 2030.

Figure 2 – Breakdown of Canada's Greenhouse Gas Emissions by Sector, 2015 (Mt CO_2e)

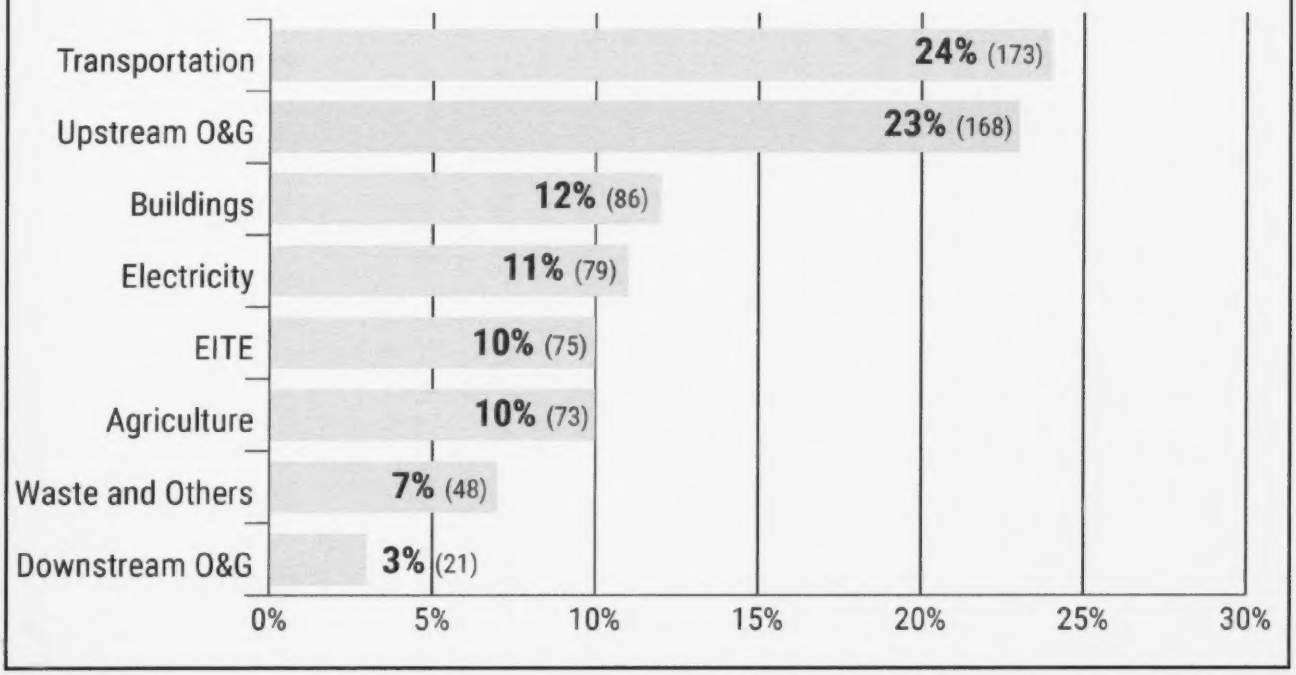


Table 1 – Emissions by Economic Sector 2005-2030 (Mt CO_2e)

	2005	2015	2020	2030
Upstream Oil and Gas	137	168	175	193
Emission-Intensive and Trade-Exposed Industries (Includes Petroleum Refining)	108	96	105	119
Electricity	117	79	71	46
Transportation	163	173	168	155
Buildings	85	86	88	83
Agriculture	74	73	71	72
Waste & Others	54	48	50	53
Total	***738***	***722***	***728***	***722***
Emission Target				***523***
Difference				***(199)***

Notes: Includes actions taken by Canadian governments, consumers and businesses put in place over the last two years, up to September 2017.

This report focuses on upstream oil and gas, while downstream oil and gas is addressed in the committee's report entitled *Decarbonizing Heavy Industry: the Low-Carbon Transition of Canada's Emission-Intensive and Trade-Exposed Industries*.

Numbers in all figures and tables may not add up to the total due to rounding.

Source: Figure 2 and Table 1 prepared by the Library of Parliament using data obtained from Canada's *Seventh National Communication on Climate Change and Third Biennial Report—Actions to meet commitments under the United Nations Framework Convention on Climate Change*, Page 155.

Carbon dioxide accounts for a majority of the anthropogenic GHG emissions released in Canada. The next major GHG is methane followed by nitrous oxide. Not all GHGs have the same radiative forcing potential. For example, over a 100 year time horizon[i], methane is 25 times more potent in trapping heat in the atmosphere than carbon dioxide and nitrous oxide is nearly 300 times more potent than carbon dioxide. Table 2 provides a breakdown of GHG emissions in Canada expressed in carbon dioxide equivalent

[i] The 100 year time horizon is consistent with reporting under the UNFCCC.

(CO_2e) a commonly used standard that facilitates comparisons by adjusting for the global warming potential of each GHG in terms of how much carbon dioxide would be required to produce a similar warming effect.[16]

The 2030 target is ambitious. According to updated projections made by Environment and Climate Change Canada in December 2017, Canada must reduce annual emissions by 199 megatonnes of carbon dioxide equivalent (Mt CO_2e) in order to meet its 2030 target. [17] To put this into context, the required reduction is above the projected emissions from Canada's entire upstream oil and gas industry in 2030, which are expected to be 193 Mt CO_2e. However, this does not mean Canada should not be ambitious; if we delay emission reduction efforts it will only become more difficult to meet future targets. Canada's Commissioner of the Environment and Sustainable Development underscored the failure by successive federal governments in implementing measures to address oil and gas industry emissions as a reason for missing past emission targets.[18]

Achieving the 2030 target will require a herculean shift in how energy is produced and consumed in Canada. For the years beyond 2030, one must imagine a society essentially transformed and decarbonized. Witnesses offered conflicting testimony on whether or not the economy would be harmed by achieving government targets. In any case, a decarbonized society means new economic opportunities, lower pollution and better air quality, improved health

Table 2 – Breakdown by Type of Greenhouse Gas Emissions, 2014 (Mt CO_2e) - 100 Year Time Horizon

Sector	Carbon Dioxide (CO_2)	Methane (CH_4)	Nitrous Oxide (N_2O)	Hydrofluorocarbon (HFCs[1])	Perfluorocarbon (PFCs[1])
Oil and Gas	143	48	1	0	0
Electricity	77	0	0	0	0
Transportation	165	0	4	3	0
EITE	73	0	2	0	1
Buildings	77	3	1	6	0
Agriculture	15	29	29	0	0
Waste & Others	23	28	2	0	0
Total	**574**	**108**	**39**	**9**	**1**

Note: Numbers in the table may not add up to the total due to rounding.

Source: Table prepared by the Library of Parliament using data obtained by Environment and Climate Change Canada, Canada's 2016 greenhouse gas emissions reference case, Detailed emissions by gas and by economic sector.

outcomes and increased productivity through more energy efficiency improvements.[19]

Canada's per capita emissions are among the highest in the world[20] and every nation's effort to address climate change adds up and collective action will be the only way to meet this challenge. *If Canada does not make a concerted effort to meet its own targets, then how can we, as an advanced economy, ask other nations to meet theirs?* Canada's global reputation and credibility would be damaged if we failed to act.

Canadians must do their part to address climate change even if Canada's portion of global emissions is relatively small at 1.6%[21] and expected to decline as emissions from emerging countries, such as China, India, Brazil and Indonesia, increase in the future.[22] The announcement by the United States (U.S.) to withdraw from the Paris Agreement challenges global climate change co-operation efforts and makes it harder to reach global emission reduction goals.

It is estimated that the global market for clean technologies is approximately $5.8 trillion per year and growing at a rate of three percent annually. Canada should not miss this opportunity to capture local economic benefits and to export technologies and expertise in clean energy solutions.[23] Reducing or capturing emissions can create whole new industries and supply chains.

At the same time, the speed and magnitude of the transition being considered will affect the lives of all Canadians. The impacts of the transition may be unevenly felt depending on income levels or geographic location. Policies should be designed to ensure that the most vulnerable in society are not adversely affected and that all Canadians have an opportunity to benefit by the move to a cleaner economy.

The question is how much of our welfare are we willing to risk to meet our climate change commitments? On the other hand, how much do we risk in delaying emission reduction policies? What is the cost of "business as usual?" If we wait until the future to act, it will likely be more costly to decarbonize since the pace of the transition would have to accelerate.

PROJECTIONS OF GLOBAL SUPPLY AND DEMAND: OIL AND GAS

Global demand for energy, including fossil fuels, is expected to grow over the next several decades. According to the International Energy Agency (IEA), oil and gas currently accounts for approximately half of all energy consumed in the world.[24] The future of petroleum commodities hinges on a number of factors including oil and gas prices, geopolitics, technology, economic growth and the success of the global community in transitioning to a low-carbon economy.[25] The IEA emphasized that the success of transitioning to zero-emitting vehicles was a major factor in the future demand for oil.[26]

The committee heard several projections about future global oil and gas demand from witnesses, many of whom cited the scenario modelling work of the IEA as the basis of their testimony. Figure 3 and Figure 4 present two scenarios that the IEA explored in their testimony to the committee; the scenarios show a range of possible future global energy demand scenarios. The scenarios demonstrate that the structure of future energy demand is strongly dependent on the stringency of global climate action. The new policy scenario in Figure 3 accounts for countries' policies and measures that were already in place as of 2016. This projection does not reach the emissions reductions goals of the Paris Agreement. The stringent climate scenario in Figure 4 illustrates global energy demand based on a 66% chance of achieving the Paris Agreement targets, which is to limit global average temperature rise to below 2°C this century.

It is worth noting that an estimated 6,000 products rely on oil and gas.[28]

Some everyday products made from petroleum (or oil and gas):

- Toothbrushes;
- Shampoo;
- Soap;
- Contact lenses, eyeglasses and sunglasses;
- Polyester fleece;
- Running shoes;
- Sports equipment;
- Computers, phones and other electronics;
- Pharmaceuticals.[27]

Approximately half of the 97 million barrels of oil used every day globally is for road transportation fuels, such as gasoline and diesel; the rest is used as feedstock in petrochemical plants, for jet fuel and bunker fuels, lubricants, heating oil and other products.[29] Products containing petroleum include plastics, textiles, and cosmetics.[30]

What is the future of the oil and gas industry in a world that must transition away from carbon emissions? Does the success in meeting Paris Agreement targets hinge on moving to zero-emitting vehicles? How can the Canadian oil and gas industry prepare for an increasingly carbon constrained world?

Is there a threat of trade action in the future, if Canadian oil and gas commodities are considered emission intensive?

Figure 3 – World Primary Energy Demand by Fuel Type in IEA's New Policies Scenario (Mtoe)

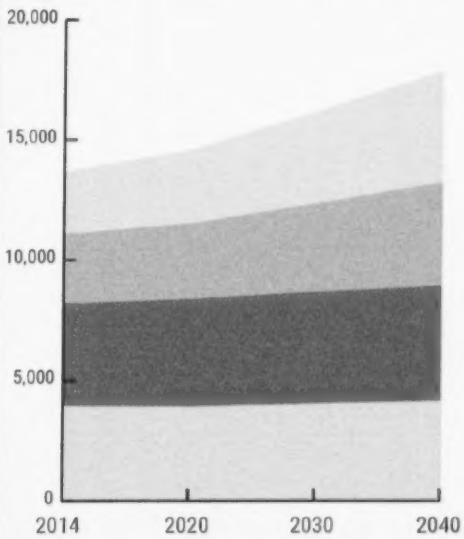
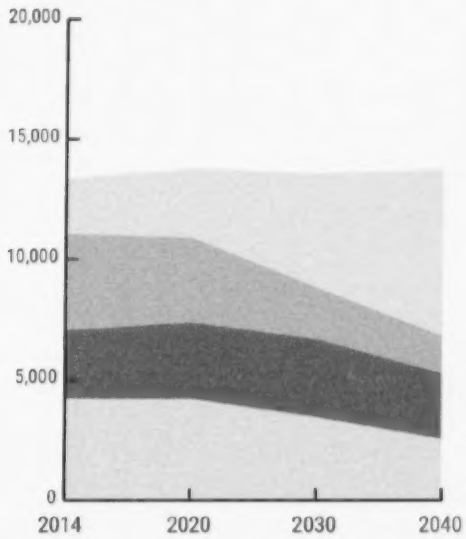


Figure 4 – World Primary Energy Demand by Fuel Type, IEA's Stringent Climate Action Scenario (Mtoe)



Oil Gas Coal Nuclear, hydro, bioenergy, other renewables

Note: Mtoe = Millions of tons of oil equivalent. "Other" includes all other forms of energy, nuclear, hydro, bioenergy, and other renewables.

Source: Figure 3 and 4 created by the Library of Parliament, Ottawa, 2017 based on data obtained from International Energy Agency, *World Energy Outlook 2016;* and from International Energy Agency and International Renewable Energy Agency, *Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System*.

CANADA'S OIL AND GAS SECTOR

Canada has significant supplies of oil and gas resources and its oil and gas industry is an important economic driver for the country. It employs directly and indirectly over 700,000 Canadians and, in 2015, it contributed $142 billion, or 7.7%, to the country's gross domestic product (GDP).[31] Canada was the fourth largest producer of crude oil in the world in 2015, with the third largest proven crude oil reserves, and was the fifth largest producer of natural gas, with the 17th largest proven natural gas reserves.[32] The industry remits $22 billion on average each year to federal, provincial and territorial governments through taxes, royalties, and land sales.[33]

The United States is virtually the only export market for Canadian oil and gas: 99% of Canadian crude exports and 100% of Canadian natural gas exports are destined for the United States. In 2015, Canada imported the equivalent of 23% of its daily production – mainly from the United States which accounted for 69% of total crude imports. Canada also received crude from Saudi Arabia (9%), Nigeria (4%), Algeria (4%), and Norway (4%).[34] Nearly all natural gas imports are imported via pipeline from the U.S. with small amounts of liquefied natural gas imported by marine vessel from Trinidad and Tobago and Norway and by truck from the U.S.[35]

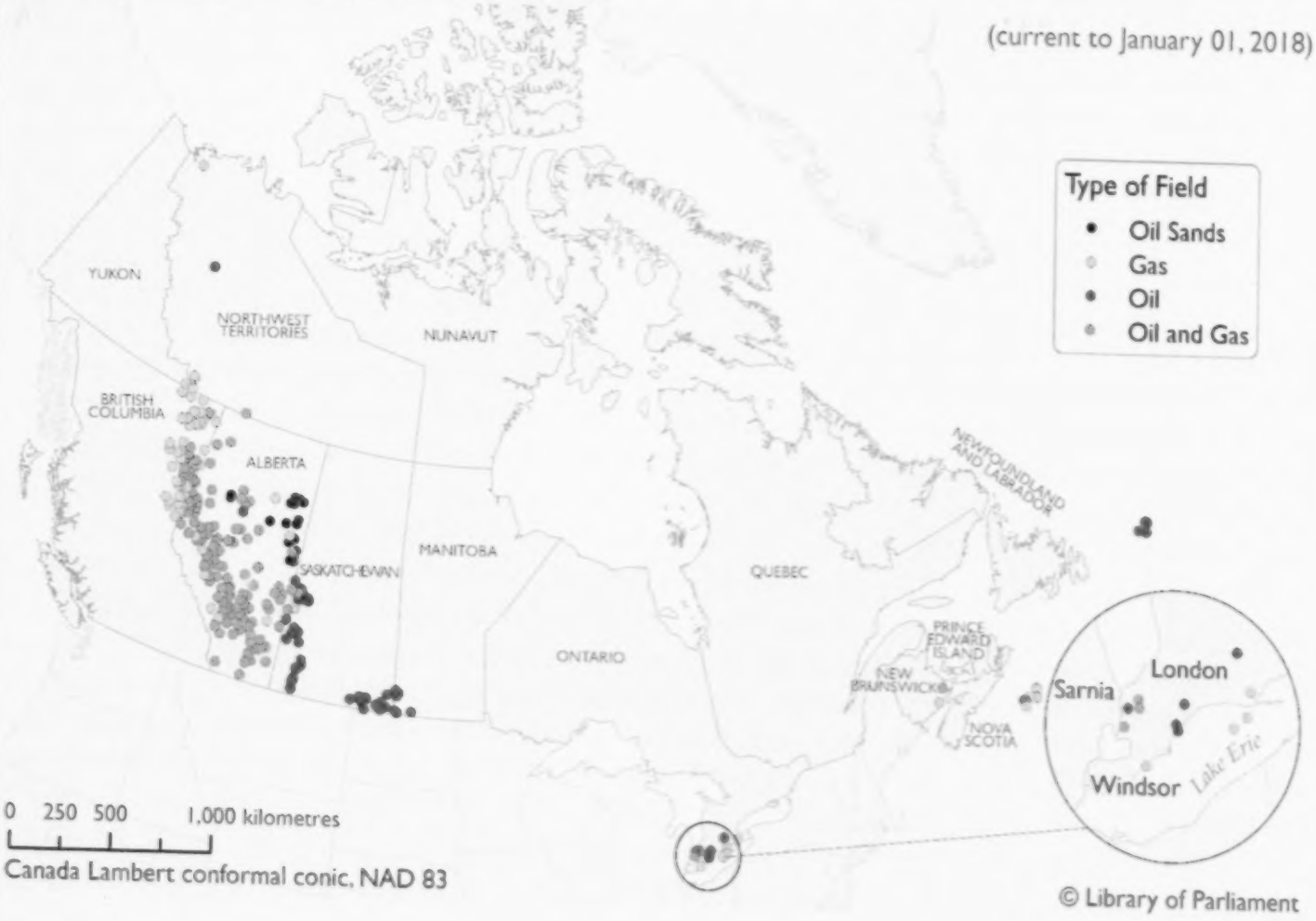
Western Canadian Crude Price Discount

This price discount is the differential between Western Canadian Select and West Texas Intermediate. Western Canadian Select is a price benchmark of a blend of mostly heavy crude (diluted bitumen) from Western Canada. West Texas Intermediate is an international benchmark for North American light crude priced out of Cushing, Oklahoma. Light sweet crude oil requires less energy to refine and typically sells for a higher price. However, distance and the logistics of moving crude to market creates price differentials that go beyond just quality of the oil.

Some witnesses spoke to the inherent risk of only having the U.S. as a buyer of Canadian fossil fuel exports. John Zhou, Vice President of Alberta Innovates, raised the issue of the price discount that Canadian producers must take when selling their products in U.S. markets, which in his estimate is "as high as $20 Canadian per barrel."[36] According to Mark Salkeld, President and CEO of the Petroleum Services

Association Canada, that price differential threatens the industry's profit margin.[37] Richard Sendall, President of the In Situ Oil Sands Alliance told the committee that it was an industry priority to build new export infrastructure to diversify the Canadian oil and gas export market.

Figure 5 – Oil and Gas Facilities in Canada, 2018



Note: Mtoe = Millions of tons of oil equivalent. "Other" includes all other forms of energy, nuclear, hydro, bioenergy, and other renewables.

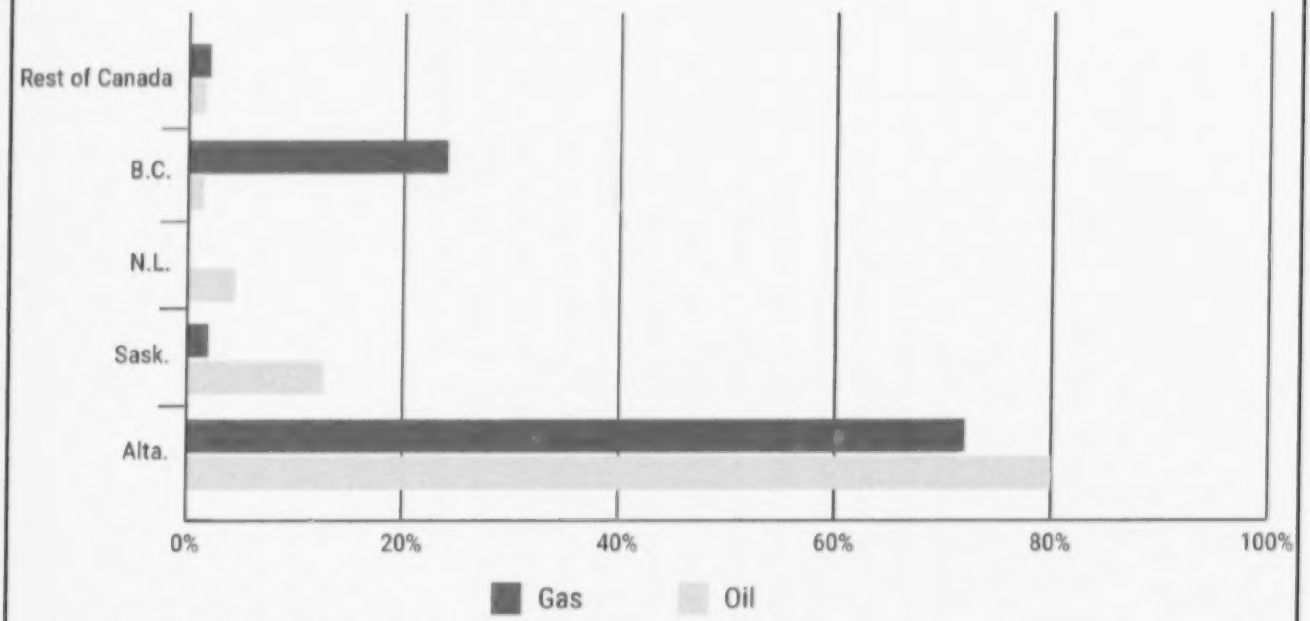
Source: Figure 5 created by the Library of Parliament, Ottawa, 2017 based on data obtained from International Energy Agency, *World Energy Outlook 2016;* and from International Energy Agency and International Renewable Energy Agency, *Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System.*

A) Regional Differences in Oil and Gas Production

Canada's upstream oil and gas production is mainly located in Alberta, British Columbia, Saskatchewan and Newfoundland and Labrador. Figure 6 shows the share of Canadian crude oil production and natural gas production by province:

- Crude oil production is dominated by Alberta, which accounts for 80% of total Canadian production, followed by Saskatchewan (12.6%), Newfoundland and Labrador (4.4%), British Columbia (1.4%), and Manitoba (1.2%). The balance of 0.4% is divided among Nova Scotia, Ontario and the Northwest Territories.
- Natural gas production is based primarily in Alberta (72%), followed by British Columbia (24%), Saskatchewan (2%), the Northwest Territories (1.1%), and Nova Scotia (1%). The balance (0.1%) is divided between Ontario and New Brunswick. Oil and gas is the economic sector that generates the largest share of provincial GDP in Alberta, Newfoundland and Labrador and Saskatchewan with 28.7%, 18.9% and 16.1% of each province's GDP respectively; in BC, the oil and gas sector accounts for 3.5% of GDP.[38]

Figure 6 – Share of Crude Oil and Natural Gas Production by Province, 2015

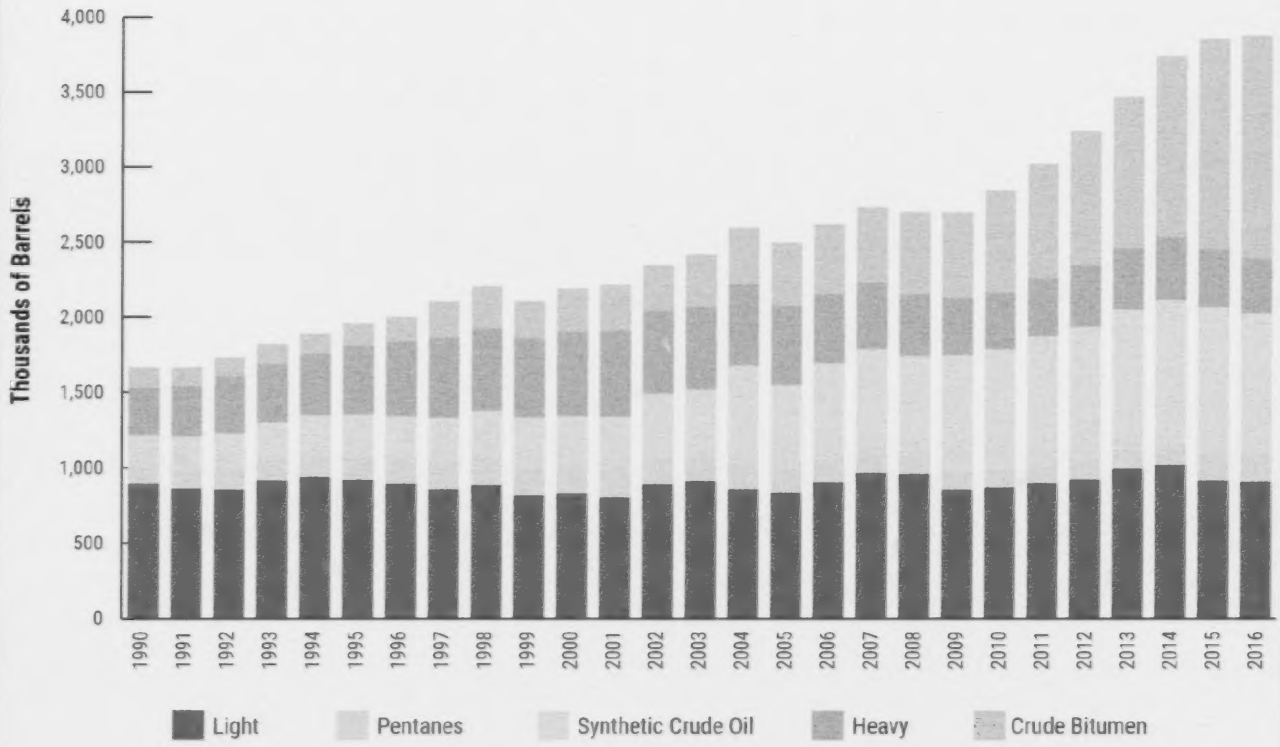


Source: Natural Resources Canada, *Energy Fact Book 2016-2017*.

B) Types of Canadian Oil and Gas

Canada produces many different types of oil depending on where and how it is extracted and processed. These types, illustrated in Figure 7, include conventional light and heavy crude oils and condensates that are drawn from the Western Canada Sedimentary Basin; the mainly conventional light crude oil that is drawn from the offshore oil fields in Newfoundland and Labrador; and the bitumen that is mined and extracted from the oil sands in Alberta. Canada also produces synthetic crude oil; an upgraded mixture of pentanes drawn from the raw natural gas stream and heavier hydrocarbons produced from bitumen.[39]

Figure 7 – Canada Daily Crude Oil and Equivalent Production by Type, 1990–2016



Note: Oil and equivalent production has increased 233% since 1990, driven by large increases in bitumen and synthetic crude production.

Source: Canadian Association of Petroleum Producers, Statistical Handbook for Canada's Upstream Petroleum Industry, July 2017.

Canada's oil sands contain 97% of the country's proven oil reserves (see box for an overview of oil sands production processes).[40] Oil sands production has exceeded conventional oil production in Canada since 2010. In fact, oil sands represented 61% of total Canadian production in 2015 (see Figure 7 for historic oil sands annual production volumes).[41] Today, over 60% of Alberta's bitumen is shipped to U.S. refiners as diluted bitumen.[42] This is bitumen that has been thinned to make it transportable in pipelines by adding diluting agents, usually natural gas condensates such as naphtha or a mix of other lighter hydrocarbons. The ratio of diluent required depends on the viscosity of the crude and the type of diluent being used, with bitumen condensate blends requiring about 30% condensates and blends that use upgraded bitumen containing up to 50% upgraded bitumen.[43] Much of the cost of the diluent, about $10 per barrel of transported oil, is unrecoverable by oil sand producers.[44]

Oil Sands Production Processes and Reclamation

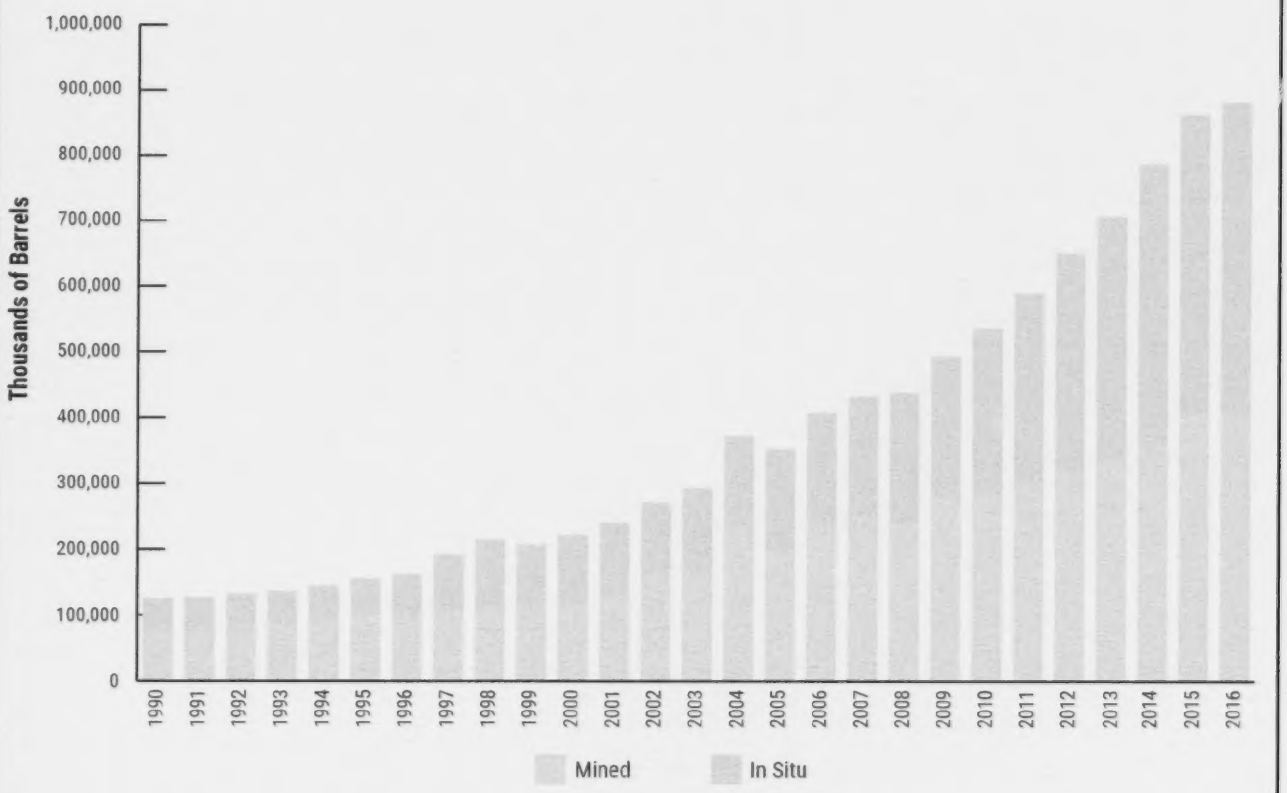
The oil sands are found beneath 142,200 square kilometres (km^2) of land in northern Alberta, extend marginally into northern Saskatchewan, and are either mined or produced in-situ. Shallow formations of 75 meters or less are mined and produce 46% of current oil sands production. The in-situ method is used for formations deeper than 75 meters, producing 54% of production and 81% of total oil sands resources.

Mined: Bitumen is mined in open pit mines. The surface land is cleared and the oil sands are collected, crushed and transported to an extraction plant where the bitumen is mixed with hot water and separated from the sand, rocks and clay. Bitumen that is recovered from this process is thick and viscous and must be diluted for shipping in pipelines, or upgraded to less viscous and lighter hydrocarbons like synthetic crude oil, along with other by-products. Fluid tailings or tailing ponds are a toxic by-product of oil sands mining. The total area occupied by tailings ponds and associated structures is 220 km^2, of which 88 km^2 is liquid surface area.

In-situ: To extract deep bitumen deposits, the main technique used is called *steam-assisted gravity drainage*, or SAGD. With this technique, heat is created (usually by burning natural gas), which is used to generate steam. The steam, often with other products like non-expandable gases to help maintain pressure in the reservoir, is injected into the thick, semi-solid bitumen deposit to warm it up and make it less viscous. The heated bitumen sinks and is collected via pipes that are located below the deposit, before being pumped to the surface for upgrading and transport.

Provincial legislation and regulations require that land used for energy resource activities is reclaimed in an environmentally sound manner. Reclamation can include returning the land for uses that are slightly different from what the land supported before the activity began. The Alberta Energy Regulator (AER) is responsible for establishing and setting the reclamation standards, criteria, and guidelines for conservation and reclamation of specified land. The AER will review reclamation applications against the current standards, criteria, and guidelines to ensure that outcomes have been achieved before issuing a reclamation certificate. Tailings ponds are similarly subject to regulatory management.[45]

Figure 8 – Canada Annual Oil Sands Production, Synthetic and Bitumen, 1990–2016

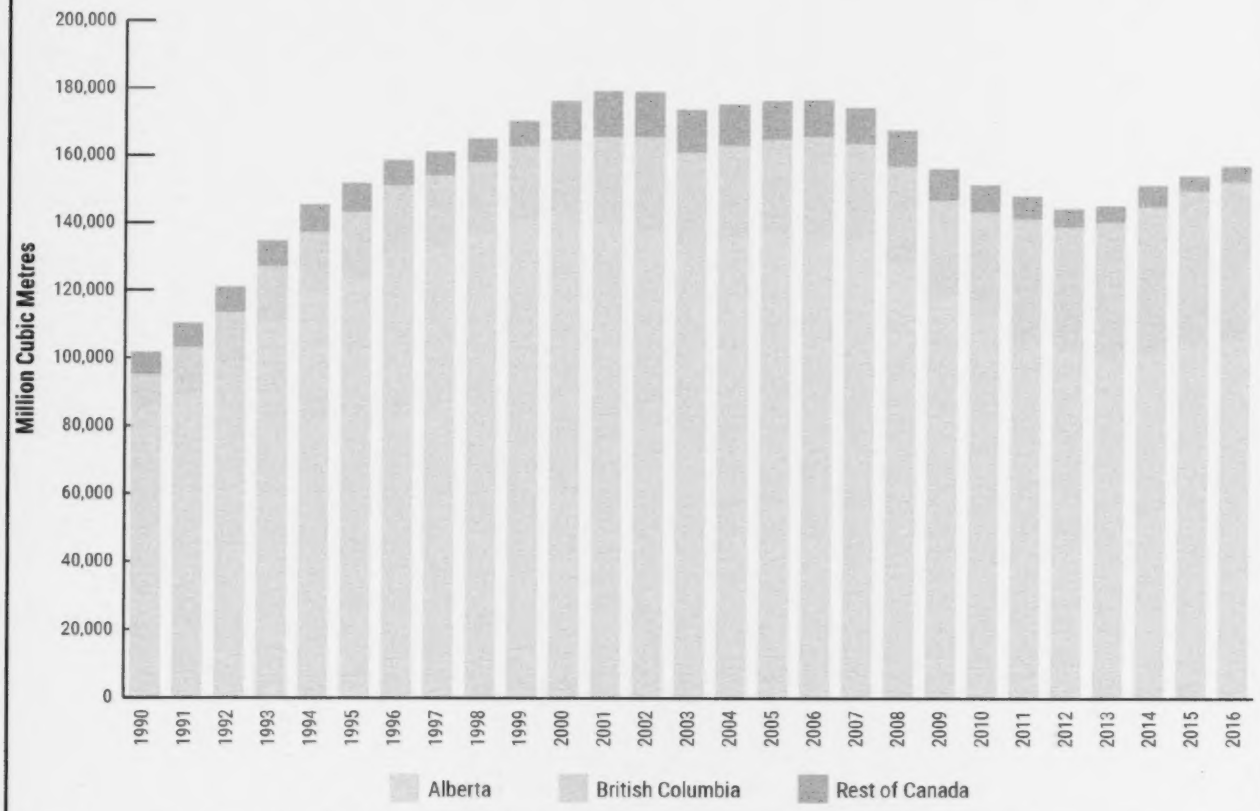


Note: Oil sands production has septupled since 1990. The year 2010 marked the point where *in situ* production has exceeded mined production.

Source: Canadian Association of Petroleum Producers, *Statistical Handbook for Canada's Upstream Petroleum Industry*, July 2017.

Some natural gas in Canada is produced by conventional drilling and as a by-product from conventional oil wells, but the majority of Canadian production – 74% of marketable production in 2015 – comes from unconventional sources including tight gas, shale gas and coal bed methane (Figure 8 presents historic annual production volumes).[46] Up to 80% of Canada's marketable reserves were found in unconventional sources in 2015.[47]

Figure 9 – Canada Annual Marketable Natural Gas Production by Province, 1990–2016



Note: Led by production declines in Alberta and the rest of Canada, marketable natural gas production has declined overall since 2001, although growth has been positive since 2013. Counter to this trend, production in British Columbia rose steadily, more than quadrupling over the period.

Source: Canadian Association of Petroleum Producers, *Statistical Handbook for Canada's Upstream Petroleum Industry*, July 2017.

There are several proposals to develop liquefied natural gas (LNG) infrastructure in British Columbia for export. At present, Canada has no facilities that cool and pressurize natural gas to a liquid state for bulk transport via tanker ship, although it can receive and re-gasify LNG in New Brunswick at the Canaport LNG import terminal. LNG in BC is also used to supplement provincial gas supply in times of peak demand, for use in certain trucks and provincial ferries. LNG is also trucked to Northwest Territories for electricity generation.[48]

Natural gas liquids (NGLs), such as pentanes, propane, butane and ethane, are captured from the raw natural gas stream at upgrader plants. Although NGL producers are part of the upstream sector, manufacturers of refined petroleum products (RPPs), such as gasoline, diesel, jet fuel and heating fuel, are considered "downstream."

C) Current Production

Table 3 shows 2015 daily production rates and total annual production for conventional and unconventional oil and gas in Canada. As noted above, these production rates make Canada the fourth and fifth largest producer of crude oil and natural gas in the world respectively.

Table 3 – Oil and Gas Production of Conventional and Unconventional Sources in Canada, 2015

Oil	Daily production rate MMb/d	Total annual production MMb/a
Conventional oil	1.5	547.5
Unconventional oil	2.4	876
Total oil	**3.9**	**1,423.5**

Natural Gas	Daily production rate Bcf/d	Total annual production Tcf/a
Conventional gas	3.7	1.35
Unconventional gas	10.7	3.9
Total gas	**14.4**	**5.26**

Note: MMb/d: Million barrels of oil per day; MMB/a: Million barrels of oil per year; Bcf/d: Billion cubic feet per day; Tcf/a: Trillion cubic feet per year

Source: Natural Resources Canada, *Energy Fact Book 2016-2017*.

D) Projected Production

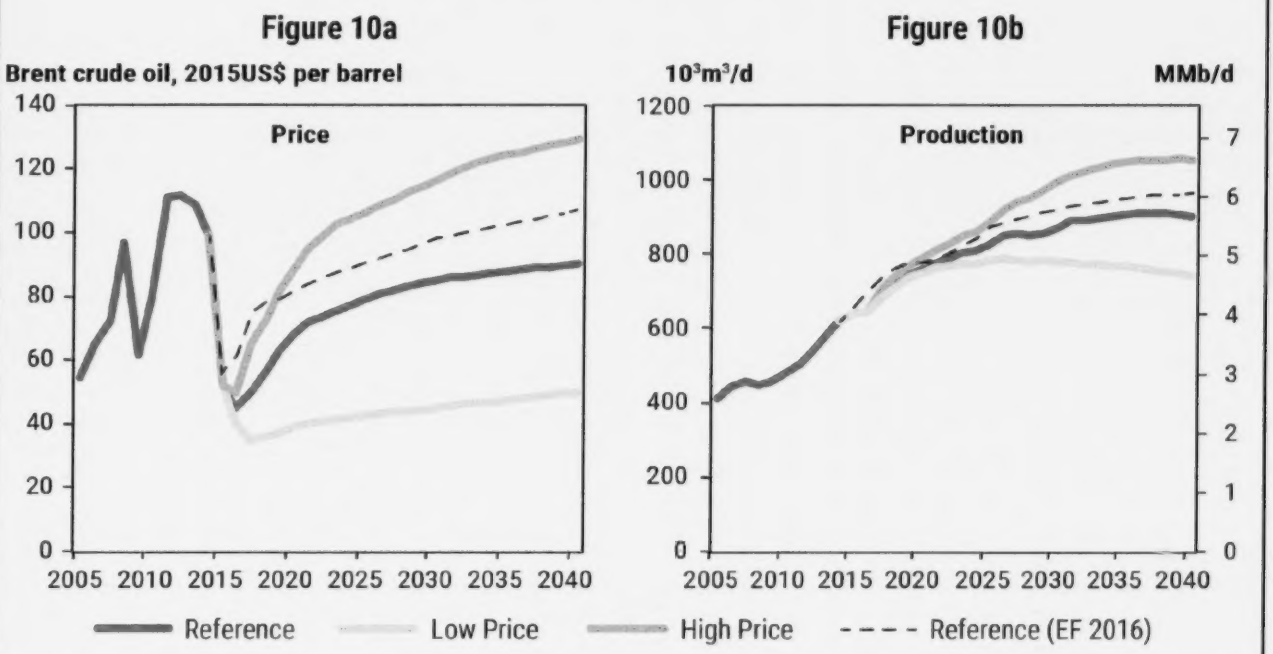
Global energy and fossil fuel demand is expected to rise in the coming few decades, but how will this affect Canadian production? To answer this question, the National Energy Board (NEB) models a range of different scenarios to explore future Canadian energy supply and demand.[49] Jim Fox, Vice President of the NEB, explained that, under a variety of energy price and macroeconomic scenarios, "[a]ll of our projections see energy production growing significantly through 2040. In our [Updated] Reference Case, Canadian oil production grows by 56 per cent to 6.1 million barrels a day by the year 2040. Natural gas production grows 22 per cent from 2014 levels to 17.9 billion cubic feet per day. Liquefied natural gas exports are a key driver of that production growth."[50]

1. Projected Oil Production

Figures 10a and 10b show different scenarios developed by the NEB regarding future oil production. Each scenario models the impact of different assumptions about oil and gas prices and macroeconomic conditions, as well as the impact of federal, provincial and territorial climate policies that had sufficient detail at the time of authoring to be modelled (see the Appendices of the NEB report for details on the policies that are included in the analysis).

The NEB scenarios include a Reference Case (a baseline outlook, based on a moderate view of future energy prices and economic growth), an Updated Reference Case (with slightly lower long-term oil and gas prices, as well as some new federal and provincial climate initiatives that were introduced prior to publication), a High Price Case (with higher long-term oil and natural gas prices), and a Low Price Case (with lower long-term oil and natural gas prices).The NEB scenarios illustrate that future oil production is price-dependent. Under the High Price scenario, projected production in 2040 is 8.2% higher than in the Updated Reference Case, while projected production in 2040 in the Low Price scenario is 23% lower than in the Updated Reference Case. The Low Price scenario sees oil production peaking in 2025.[51]

Figure 10a and 10b – Crude Oil Price Assumptions and Total Oil Production, NEB Reference, High and Low Price cases



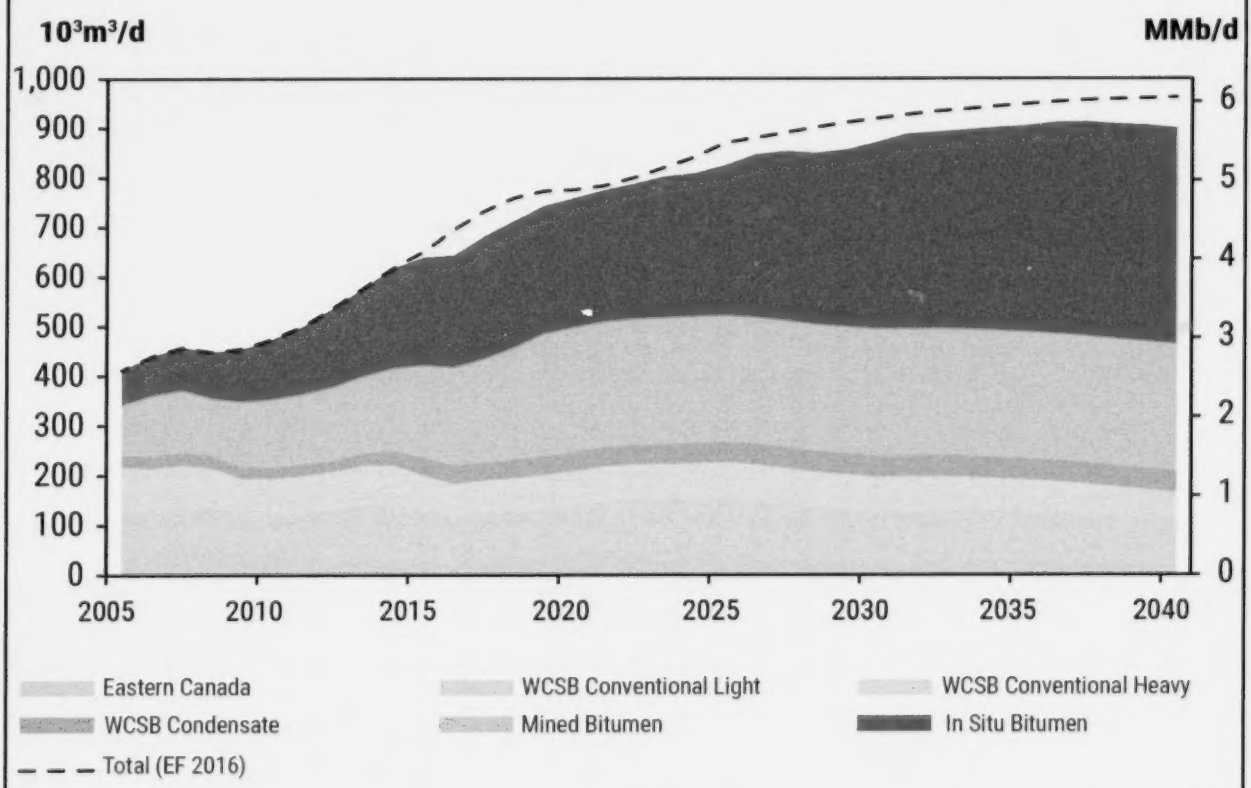
Note: The chart on the left shows the NEB's macroeconomic and price scenarios and the chart on the right shows the projected production for each scenario. The dotted line in each chart is the NEB's interim Updated Reference Case. High prices and macroeconomic conditions lead to higher production.

Source: National Energy Board, *Canada's Energy Future 2016: Update – Energy Supply and Demand Projections to 2040*, 2016.

Figure 11 presents the NEB's projections of the production levels of different types of oil under the Original Reference Case. According to these projections, it is estimated that by 2040:

- Oil sands production will reach 4.3 MMb/d, a 72% increase from 2015 levels. In-situ will supply 2.7 MMb/d of oil sands production in 2040, or 63% of the total.
- Conventional light oil production will reach 559 Mb/d, a 15% decrease from 2015 levels.
- Conventional heavy oil production will reach 368 Mb/d, a 15% decrease from 2015 levels.
- Barring new offshore resource discoveries, offshore oil production will reach 122 Mb/d, a 30% decrease from 2015 levels.[52]

Figure 11 – Total Canadian Crude Oil and Equivalent Production, NEB Reference Case



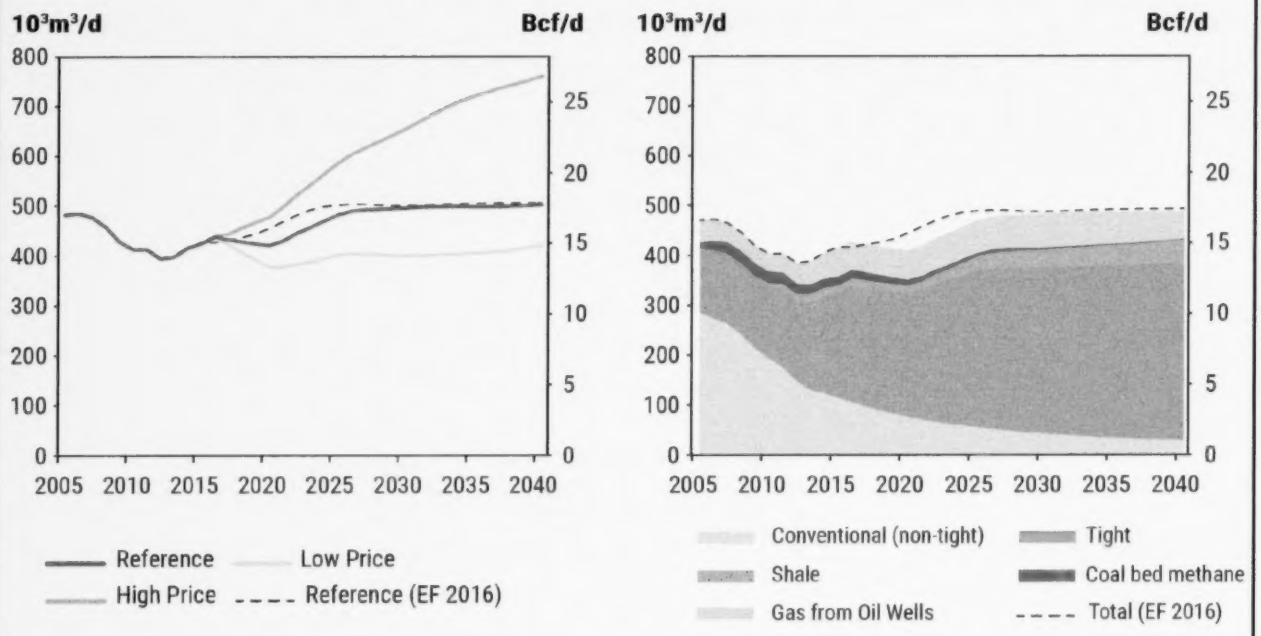
Source: National Energy Board, *Canada's Energy Future 2016: Update - Energy Supply and Demand Projections to 2040*, 2016.

2. Projected Natural Gas Production

The left chart in Figure 12 presents the NEB's projections of future natural gas production according to their modelled scenarios, while the chart on the right presents the view of natural gas production by type under the Original Reference Case scenario. All scenarios assume that liquefied natural gas (LNG) exports start from the British Columbia coast beginning in 2021 to reach 2.5 Bcf/d of LNG exports by 2025. Under the Updated Reference Case, total natural gas production in 2040 grows by 18.5% over 2015 levels. The Original Reference Case shows a continued decline in conventional natural gas and a large increase in tight gas production, particularly during the 2020–2026 period as LNG exports are assumed to come online.

The scenarios show that natural gas production is price-dependent. Under the High Price scenario, projected production in 2040 is 50% higher than in the Updated Reference Case, while 2040 production in the Low Price scenario is 17% lower than in the Updated Reference case.

Figure 12 – Total Canadian Marketable Natural Gas Production Under Several Scenarios and Natural Gas Production by Type under the Reference Case



Source: National Energy Board, *Canada's Energy Future 2016: Update - Energy Supply and Demand Projections to 2040*, 2016.

Regarding the NEB's assumptions about future LNG production, Jim Fox explained the following:

> *Canadian LNG projects are expected to operate in a vertically integrated fashion where the proponents own the reserves, the production facilities and the liquefaction plants. As a result, any amount of LNG exports would have a direct relationship to the amount of natural gas produced in Canada in that it would go up and down by the amount exported. LNG exports would not seem to have any impact on the amount of natural gas available for Canadian consumers.*[53]

The corollary of this is that if LNG exports are not brought online as assumed in the NEB scenarios, overall natural gas production will be lower in Canada. To test the effect of this, the NEB modelled three different LNG capacity scenarios (a reference case and a high- and no-LNG export case). It found that in 2040 a high-LNG scenario would produce 7 billion cubic feet per day (Bcf/d) more natural gas than the no-LNG case, which is equivalent to about half of current production.[54]

During a fact finding visit to Hamilton, Ontario, committee members were told by city officials and Union Gas representatives that Hamilton's Biogas Purification Unit processes up to 10,000 cubic metres of renewable natural gas per day (equivalent of heating 1,200 homes) and then injects it to the Union Gas distribution grid.

CANADIAN UPSTREAM OIL AND GAS EMISSIONS AND TRENDS

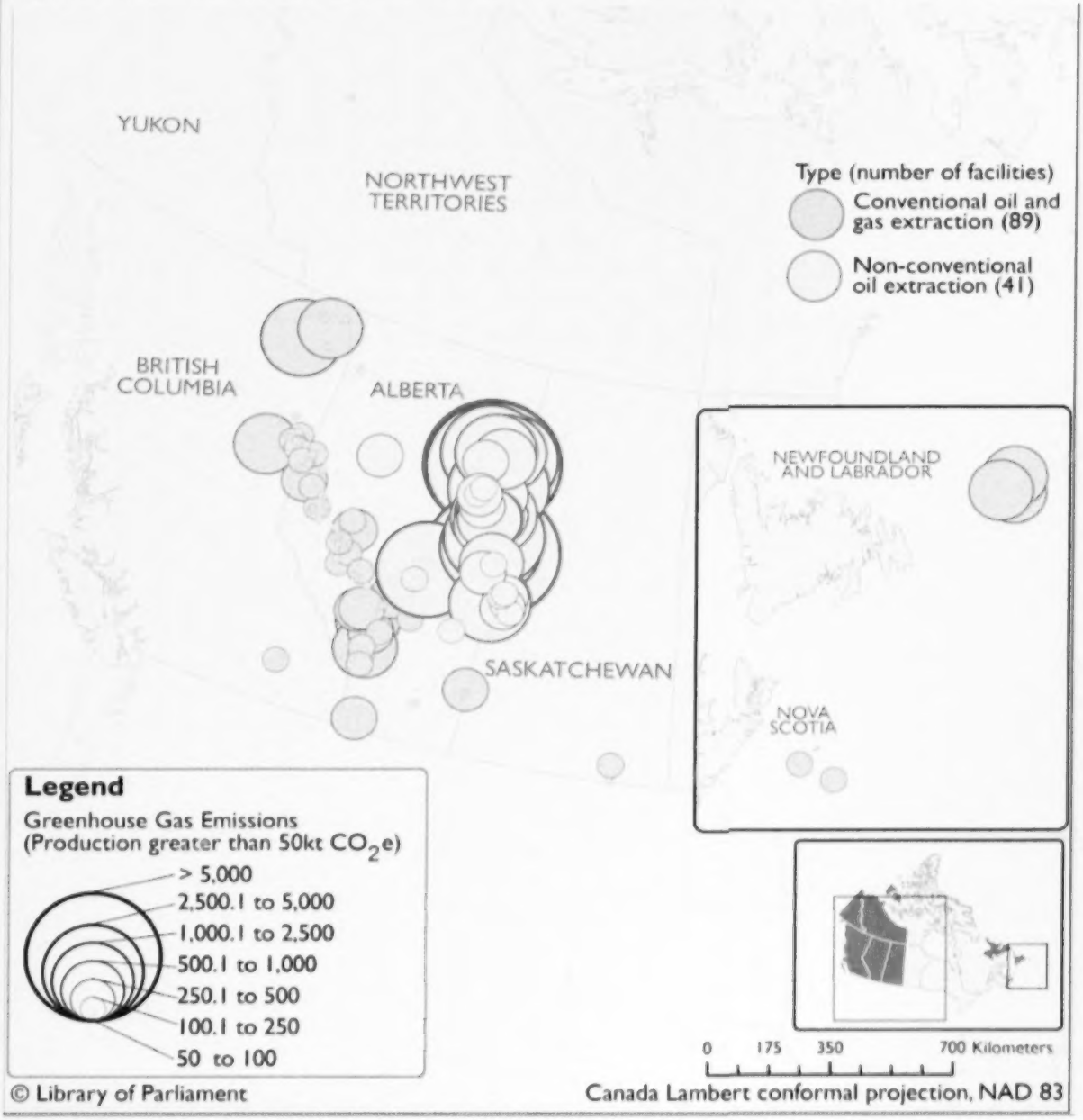
Canada's oil and gas industry, including both the upstream and downstream sectors, is responsible for producing the greatest share of Canada's GHG emissions – 189 Mt CO_2e in 2015, or 26% of the total.[55] Upstream oil and gas emissions were 23% of total Canadian emissions, while downstream were 3% of the total.[56] As previously stated, downstream oil and gas emissions associated with the refining sector are addressed in the committee's report on emissions-intensive and trade-exposed industries.[ii]

Figure 13 maps the emissions from conventional and unconventional upstream oil and gas operations with emissions greater than 50 kilotonnes (kt) CO_2e in 2015. The map shows that GHG emissions from the sector are highly concentrated in specific areas of the country, with Alberta producing the most GHG emissions. The largest emitting sources come from non-conventional oil extraction operations.

Members of the committee met with Irving Oil representatives during a fact finding visit in Saint John, New Brunswick.

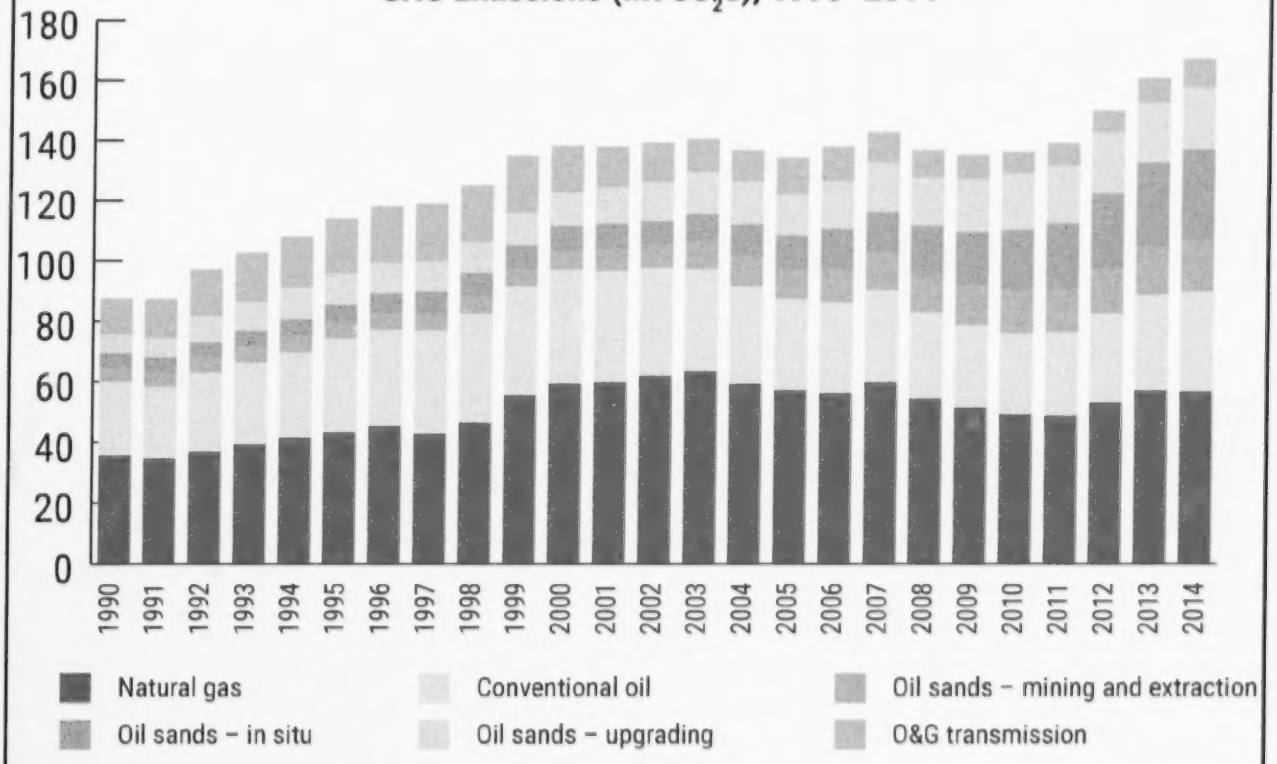
[ii] According to Environment and Climate Change Canada, National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada, upstream oil and gas GHG emissions include those associated with the stationary combustion, on-site transportation, electricity and steam production, fugitive and process emissions arising from natural gas production and processing, conventional oil production, offshore and arctic oil production, oil sands production (mining and in-situ) and upgrading, as well as combustion and fugitive emissions from the transport and storage of crude oil and natural gas. Downstream oil and gas GHG emissions include the same types of emissions, but for the petroleum refining industries, as well as those associated with the combustion and fugitive emissions from local distribution of natural gas.

Figure 13 – Greenhouse Gas Emissions from Oil and Gas Extraction Facilities, 2015



Source: Map prepared by the Library of Parliament, Ottawa, 2017, using data from Environment and Climate Change Canada. Greenhouse Gas Emissions for Large Facilities, Canada, 2015; Ottawa: Environment and Climate Change Canada, accessed September 2017; Natural Resources Canada (NRCan). Boundary Polygons. In: *Atlas of Canada National Scale Data 1:5,000,000 Series*. Ottawa: NRCan, 2013. The following software was used: Esri, ArcGIS, version 10.3.1. Contains information licensed under Open Government Licence – Canada.

Figure 14 – Canada Upstream Oil and Gas Sector GHG Emissions (Mt CO_2e), 1990–2014



Source: Environment and Climate Change Canada, National and Provincial/Territorial Greenhouse Gas Emission Tables, D-Tables-Canadian-Economic-Sector-Provinces-Territories.

A) Absolute Emissions and Trends

The GHG emission profile of Canada's upstream oil and gas sector has increased in recent years. As shown in Figure 14, absolute upstream GHG emissions have nearly doubled over the period, rising to 167.1 Mt CO_2e in 2014, because of significant rise in oil sands GHGs.[57] The following elements are noteworthy:

- In 2014, natural gas emissions rose by 59% from 1990 levels, reaching 56.7 Mt CO_2e, while natural gas production increased by 49%.
- In 2014, conventional oil emissions rose by 35% from 1990 levels, reaching 33.1 Mt CO_2e. Emissions peaked in 2000 and steadily declined before rising since 2009, while conventional oil production increased by 16%.
- In 2014, oil sands emissions rose by 339% from 1990 levels, reaching 67.6 Mt CO_2e,

while oil sands production rose by 528%. Since 1990:

- Mining and extracting GHGs grew by 282%;
- In-situ GHGs grew by 523%;
- Upgrading GHGs grew by 236%.

- In 2014, oil and gas transmission emissions associated with combustion and fugitive emissions from the transport and storage of crude oil and natural gas have decreased by 20% from 1990 levels, reaching 9.7 Mt CO_2e.

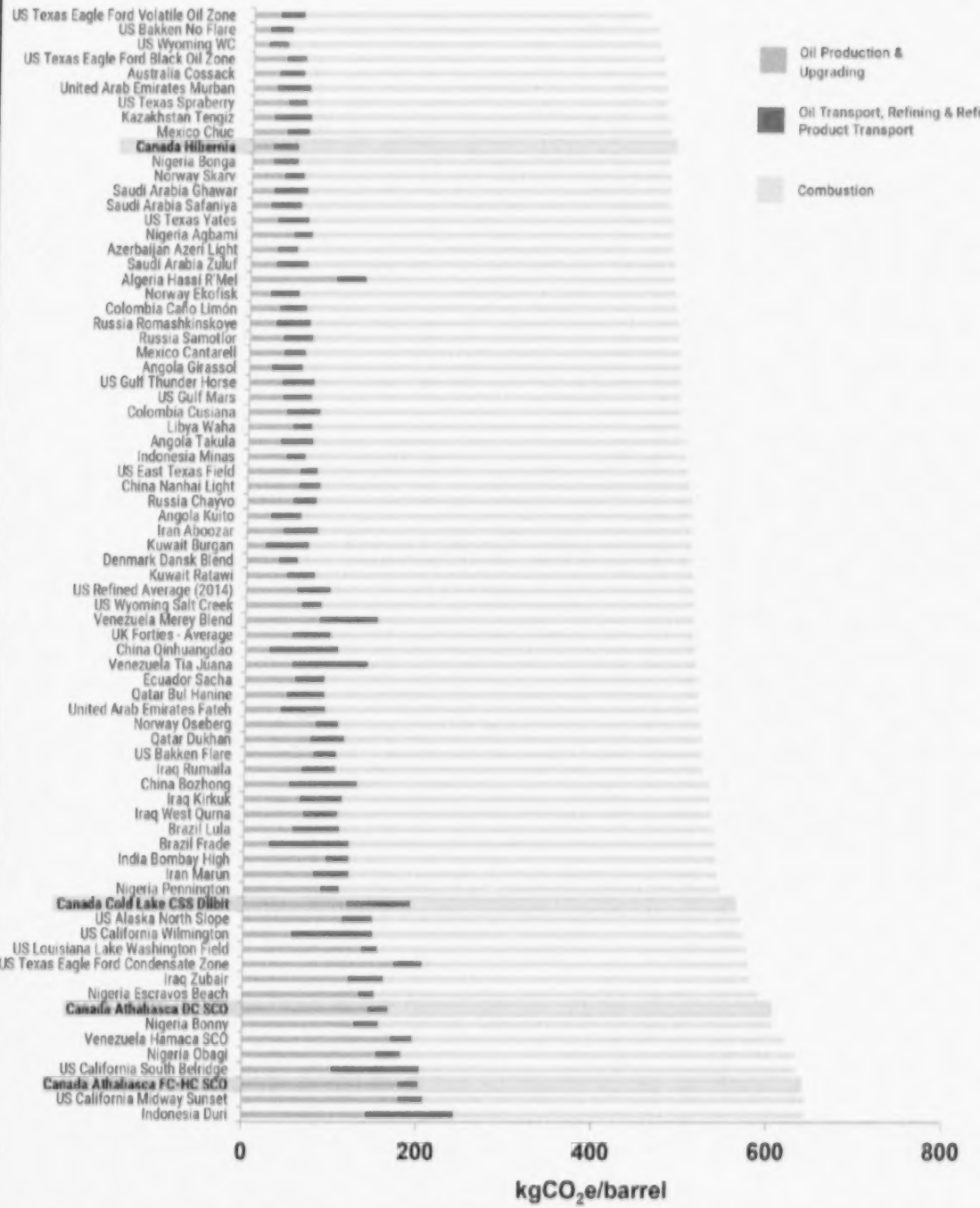
B) Emission Intensity

Emission intensity is the measure of the average rate of GHG emissions associated with an activity like producing oil and gas. A common indicator in the oil sector is kilograms of carbon dioxide equivalent per barrel of oil (kg CO_2e bbl), while the natural gas sector measures emissions on a kilograms of carbon dioxide equivalent per barrel of oil equivalent (kg CO_2e/boe) basis.

> *In 2014, oil and gas transmission emissions associated with combustion and fugitive emissions from the transport and storage of crude oil and natural gas have decreased by 20% from 1990 levels, reaching 9.7 Mt CO_2e.*

Leah Lawrence, President and Chief Executive Officer of Sustainable Development Technology Canada presented a chart which compares the emission intensity of different Canadian crude oils to many international crudes (see Figure 15). The chart shows that several Canadian crude oils have higher emission intensity than their international comparisons. On the other hand, Richard Sendall, Chairman of the In Situ Oil Sands Alliance, noted that "of the top oil reserve holders, Canada is the only one that abides by world-class, stringent environmental regulations and oversight and is the sole major producing jurisdiction with comprehensive GHG regulations."[58] Canada's offshore oil production is the exception, having an emission intensity that is among the lowest in the field.

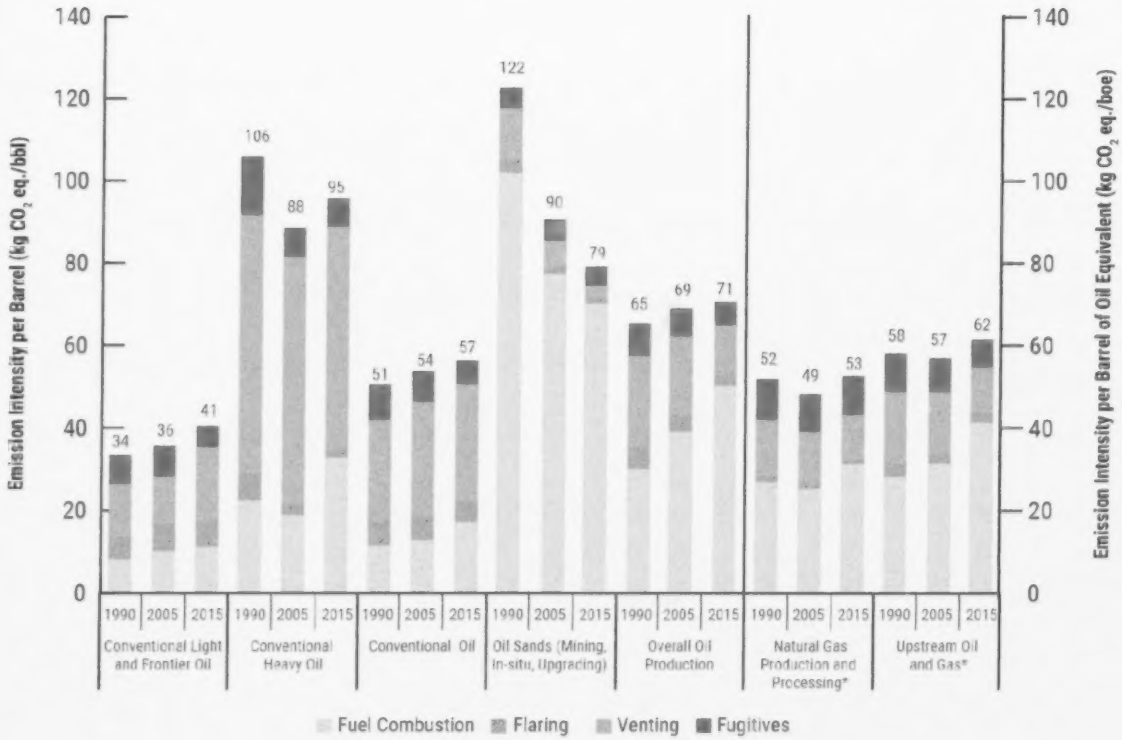
Figure 15 – Comparison of Emission Intensity of Different Types of Oil



Source: Sustainable Development Technology Canada

As several witnesses noted, it is important to recognize that each type of oil and gas has a different emission profile.[59] Figure 16 shows the emission intensity by source type for Canadian oil and gas in 1990, 2005 and 2015.[60] In 2015, the average barrel of conventional light and frontier oil had the lowest emission intensity. Next was conventional oil, followed by oil sands, and conventional heavy. Natural gas placed between conventional light and frontier oil and conventional oil in terms of relative emission intensity.[61]

Figure 16 – Emission Intensity by Source Type for Oil and Gas (1990, 2005 and 2015)



Notes:
Intensities are based on total subsector emissions and relevant production amounts. They represent overall averages, not facility intensities.

*Calculated on a barrel of oil equivalent (boe) basis by converting production volumes to energy basis and then dividing by energy content of light crude oil.

1 barrel (bbl) = 0.159 m^3

Note: The category *Overall Oil Production* represents the emission profile of the average Canadian barrel of oil based on the production levels and emission intensities of each type of oil produced in a given year. The category *Upstream Oil and Gas* represents the emission profile of the combined production of Canadian oil and gas on an equivalent basis.

Source: Environment and Climate Change Canada, National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada 1990-2015, Part 1.

The emission profiles in Figure 16 also show that the sources of GHG emissions vary by type of oil and gas production. For example, in-situ GHG emissions are created mainly from fuel combustion while the greatest share of GHG emissions from other types of oil comes from venting.[iii] This is because the in-situ process burns natural gas to produce heat to generate steam.[62] Conventional light and frontier oil, on a proportionate basis, produce more emissions from flaring than for any other type of oil.[63] As Robert Cadigan, President and CEO of the Newfoundland and Labrador Oil & Gas Industry Association explained, this flaring is a safety measure to prevent dangerous operations in the technically-demanding offshore oil rig environment, and it would be challenging to retrofit existing rigs to flare less due to technical constraints.[64]

As illustrated in Figure 16, the emission intensity of natural gas production had improved between 1990 and 2005, but these gains had been erased by 2015.[65] Compared to all types of Canadian oil, natural gas produced more fugitive emissions on both an absolute and relative basis.[66]

Finally, Figure 16 demonstrates that in-situ production has made significant improvements in emission intensity since 1990, with a 35% emission performance improvement over the period.[67] On the other hand, as in-situ oil production has exceeded conventional oil production since 2010, the overall emission intensity of Canada's oil industry has increased.[68] For example, between 1990 and 2015, overall oil production emission intensity increased by 9%. As NEB projects significant growth in in-situ production, Canada's upstream oil sector emission intensity will continue to increase unless improvements to in-situ emission intensity are made.

[iii] Venting is the controlled release of gases, while flaring is the controlled burning of gases.

POLICY OPTIONS: WHAT WE HEARD

Canada's oil and natural gas resources are an enormous economic and strategic asset. They represent massive industrial activity supplying jobs and economic wealth and prosperity for the country, particularly in western and Atlantic Canada.

At the same time, the extraction and production of this oil and gas represents one of Canada's largest sources of GHG emissions and GHG emissions growth. IEA estimates indicate that the world will still require substantial amounts of oil and natural gas for decades to come, the level of which will depend on how countries collectively respond to climate change. For Canada, the challenge is ***how to sustainably develop and optimize the value of our oil and gas resources while meeting emission reduction commitments.***

Andrew Leach, Associate Professor at the University of Alberta explained the challenge as follows: "...you have a two-part problem. One is how to reduce emissions from our oil and gas sector domestically, but the more important one is how to prepare our oil and gas sector to compete for market share in a carbon-constrained world."[69]

In general, witnesses were optimistic that clean technology and a mix of flexible and stringent policies could improve the emission intensity in the oil and gas sector. Mark Jaccard, for example, explained to the committee that an increasingly stringent carbon tax along with compulsory, flexible regulations would "incentivize the switch from high-carbon to low-carbon technologies and fuels."[70] On the other hand, others spoke practically about the challenge that the sector faces in reducing emissions. For example, Robert Cadigan, President and CEO of the Newfoundland and Labrador Oil & Gas Industries Association noted that "emissions can only be reduced based on what is technically feasible. Even if money were no object, emissions can only be reduced to a certain level."[71]

In effect, at least for projects that are already in operation, there is a certain amount of current GHG emissions that are locked-in. As Christopher Ragan, Chair of Canada's Ecofiscal Commission, explained, the ability of emissions-intensive sectors, such as the oil and gas sector, to reduce their emission intensity is constrained, even in the face of robust policy signals like a high carbon price.[72]

The federal government is considering a range of policy tools to achieve emission reductions in the oil and gas sector, including carbon pricing and methane emissions regulations. Other measures are outlined as possible considerations in the final report of the federal/provincial/territorial Working Group on Specific Mitigation Opportunities.[73] Other policy options include the adoption of regulations and incentives to increase the use of electricity in industrial processing, to improve energy efficiency, to reduce flaring, to accelerate the deployment of carbon capture and sequestration, and to implement measures to drive breakthrough technologies.

> *"...some witnesses argued that if one looks too narrowly at trying to reach Canada's domestic emission targets, then it may miss opportunities to reduce overall emissions worldwide."*

The overall goal of these policy tools is to reduce domestic emissions, but some witnesses argued that if one looks too narrowly at trying to reach Canada's domestic emission targets, then it may miss opportunities to reduce overall emissions worldwide. This view was put forward by David Keane, President and Chief Executive Officer of BC LNG Alliance who explained that Canada has an opportunity to reduce global emissions by exporting liquefied natural gas to China and other Asia-Pacific countries that rely on higher emitting fuels, such as coal. He said: "the export of Canada's abundant natural gas as LNG to countries seeking to reduce their dependence on coal for energy is the most significant global greenhouse gas abatement effort that Canada can provide."[74]

Would the export of Canadian LNG result in significant emission reductions worldwide? If so, should the export of Canadian LNG used to displace higher emitting fossil fuels in other countries be part of the domestic strategy to reduce emissions?

A) Carbon Pricing

Carbon pricing is a central component of the Pan-Canadian Framework on Clean Growth and Climate Change and marks new fiscal territory for the federal government. By 2018, a national broad-based carbon benchmark price will be applied in all provinces and territories starting at $10 per tonne of carbon dioxide equivalent (t/CO_2e). The benchmark will increase by $10 each year through 2022, when it will reach $50 t/CO_2e.[75]

As described in the Framework, each jurisdiction can choose between a carbon tax, a hybrid approach composed of a carbon tax and an output-based pricing system, and an emissions trading scheme (cap and trade) –see below for description of carbon pricing options. If a province or territory does not implement a carbon pricing system that aligns with the federal benchmark, the federal government will implement, as a backstop, a federal carbon tax applied to fossil fuels and an output-based pricing system for large industrial emitters for that province or territory (see Carbon Pricing

Options section below).[76] Revenues will be returned to the province or territory from which they were collected.[iv]

Under the backstop, large industrial emitters will pay a carbon tax if they emit above a performance threshold while efficient facilities may pay no tax or even receive emission credits. According to the federal government, the output-based pricing system is expected to create a pricing incentive that reduces

> *... greenhouse gas emissions from industrial facilities while limiting the impacts of carbon pricing on their international competitiveness, particularly on their ability to compete with similar businesses in countries that do not have carbon pricing. This approach thus minimizes the risk that businesses could move from Canada to jurisdictions that do not price carbon.*[77]

On 15 January 2018, the Government of Canada released draft legislation on the federal backstop for public comment.[81] The backstop provides the minimum threshold to which provinces and territories must design and implement their carbon pricing systems. The backstop will supplement or "top-up" systems that do not

Carbon Pricing Options

Carbon tax: A government-imposed tax on carbon, usually implemented by taxing fossil fuels but it can be designed to apply to non-combustion emissions such as industrial venting or fixed process emissions.[78]

Cap and trade: An approach to controlling carbon emissions that requires a government to cap total carbon emissions on regulated sectors (usually large emitters) and either sells or gives carbon permits to companies (large emitters) that add up to the cap. Companies that are successful in reducing emissions can sell permits (also referred to as carbon credits or allowances) that they do not use to other companies emitting above their permits. The price of permits varies depending on the market for permits. Over time, governments introduce stringency by lowering the overall cap.[79]

Carbon Tax and Output-Based Pricing System: A carbon pricing system that combines a carbon tax with a high performing benchmark feature for large emitters. This feature is sometimes called an output-based allocation system or performance-based emission system. Under an output-based pricing system, governments set a high performing benchmark based on an emission intensity basis, for example CO_2 per ton of steel. Each regulated emitter is allocated free emissions credits that correspond to what their emissions would have been if their emission intensity had matched the benchmark. A company will have a carbon liability for any emissions it does not have emission credits to cover. This would .happen if a company's emission intensity fails to reach the benchmark. In this case, the company would have to pay the carbon tax on, or buy credits to cover, its excess emissions. If its emission intensity outperforms the benchmark then it receives performance credits, which it can sell. Governments can introduce stringency by setting higher performing benchmarks.[80]

[iv] The carbon tax under the federal backstop will come into effect in 2018 while the output-based pricing system will not come into effect before January 1, 2019.

fully meet the national benchmark.[82] Provinces and territories have until September 1, 2018 to outline how their carbon pricing systems will meet the federal benchmark.[83] The federal government indicated that it will continue to engage provincial and territorial governments, Indigenous Peoples and other affectted stakeholders on the design of the federal carbon pricing system during the winter and spring of 2018.[84]

In May 2017, committee members participated in a public forum at Dalhousie University in Halifax, Nova Scotia. Students, faculty and community members were invited to an open discussion with the senators on their study on the transition to a low-carbon economy.

Several provinces, including some that produce oil and gas, already have carbon pricing regimes in place or have announced the establishment of such a regime. For ex-ample, Alberta introduced a broad carbon tax on fossil fuels in 2017, which is now set at $30/tonne. As well, it replaced the Specific Gas Emitters Regulations that applied to large industrial emitters with the Carbon Competitiveness Incentive Regulation, an output-based allocation approach that came into force on 1 January 2018 (see the box for description of carbon pricing options).

British Columbia, which has a $30 per tonne carbon tax on fossil fuels, has proposed to increase the tax by $5 per tonne per year starting on 1 April 2018 until rates reach $50 in 2021. Both Quebec and Ontario have a cap-and-trade system, in operation since 2013 for Quebec and since 2017 in the case of Ontario. Both systems are integrated in the Western Climate Initiative, along with California. Manitoba announced a $25 carbon tax levied on fuels and natural gas starting in 2018. The province will also be introducing an output-based carbon price during 2019.[85] Finally, in September 2017, Nova Scotia introduced legislation to implement a cap and trade system. At this time, the carbon pricing plans of other provinces and territories have not been formalized or announced.

From an economic efficiency perspective, Jennifer Winter of the University of Calgary explained that carbon pricing is favoured by economists because it can theoretically "achieve the maximum benefit at the minimum [economic] cost."[86] Trevor McLeod, Director of the Centre for Natural Resources Policy at the Canada West Foundation echoed Ms. Winter's position, stating that "[a]s an organization, we believe that a market mechanism makes the most sense and a carbon tax is the most efficient way to reduce greenhouse gas emissions."[87]

Witnesses differed in their opinions about how carbon pricing programs should be designed and implemented, but were mostly consistent in placing carbon pricing at the centre of any approach to reducing overall Canadian GHG emissions and those of the upstream oil and gas sector.

Witnesses differed in their opinions about how carbon pricing programs should be designed and implemented, but were mostly consistent in placing carbon pricing at the centre of any approach to reducing overall Canadian GHG emissions and those of the upstream oil and gas sector. Benjamin Dachis, Associate Director of Research at the C.D. Howe Institute, called for a "transparent price on carbon as the main tool to reduce emissions."[88] He also noted: "The key thing for you to remember as part of your study is that the single-most important thing that any government can do to transition to a low-carbon economy is to introduce a carbon price."[89]

Mr. Dachis noted that carbon pricing policies that reflect the social cost of the damages caused by pollution will drive demand for clean technologies throughout the economy. Without carbon pricing that reflects the social costs of the damages caused by pollution, he explained, "newly developed low-emission technologies are just not going to spread throughout the marketplace. There must be demand for low-emission technology [because] just pushing supply of low-emissions technology through subsidies is not going to be enough."[90]

Furthermore, Richard Sendall, Chairman of the In Situ Oil Sands Alliance, explained that in his industry, Alberta's carbon price adds "impetus to move down that chain of higher efficiencies and develop new processes to more efficiently extract the resource, and just that price signal spurred us on [...] to be more efficient and more cost-effective in conducting our business."[91]

Carbon pricing helps create a level playing field between alternative sources of energy as well as between different types of oil. Aad van Bohemen of the International Energy Agency explained that not only should the environmental impact of oil and gas production be regulated, but that a level playing field among fossil fuels should be achieved. He said:

> *...the impact should be priced so that you create a level playing field among the fossil fuels according to their environmental impact. That level playing field will decide which fossil fuels we will produce with the lowest impact on the environment. [...] if we look at the projections globally the world still needs a lot of oil, coal and gas [...] There should be an effort to produce those fossil fuels with an environmental impact that is as least as possible.*[92]

On the other hand, Mark Jaccard, Professor at Simon Fraser University, noted that while carbon pricing may be the most economically efficient way to reduce emissions in theory, outcomes may be sub-optimal in practice.[93] He also stressed that governments have choices in their policy approaches to reducing GHGs, and that efficiency arguments aside, there are other climate policy instruments that can be used to achieve the same results:

> *Any economy can achieve near-zero carbon emissions via regulations alone or via carbon pricing alone. Governments have to decide which policy, or combination of these, to employ based on their balancing of standard policy evaluation criteria, especially the criteria of economic efficiency balanced with political acceptability, because really effective climate policy-making is very politically difficult, and it always will be.*[94]

Competitiveness Risks

Many witnesses, while accepting that a carbon price is effective at reducing emissions, nevertheless expressed concern that carbon pricing could lead to competitiveness risks for the emissions-intensive and trade-exposed sector like the oil and gas industries. Speaking on behalf of his members, Mark Salkeld of the Petroleum Services Association of Canada explained the following:

> *...we know we need robust regulation. We know we need incentive to move to a cleaner future. There is no denying that. Our members are not dinosaurs. They know we have to move that way. As to introducing a carbon tax and the basic economics to incent an industry to shift, I don't see those as coming too fast. On behalf of our membership, they're aware of it. They're working towards it. They know it's coming. They know we need it.*[95]

> *"Competitiveness concerns arise in situations where there are carbon price differentials between jurisdictions."*

That said, Mr. Salkeld warned that the goal of carbon pricing policies should be to not "detrimentally impact business. We don't want to drive businesses out. We want to allow them the opportunity to transition, those businesses that are open to transition."[96]

Competitiveness concerns arise in situations where there are carbon price differentials between jurisdictions. Chris Ragan, Chair of Canada's Ecofiscal Commission defined the concept by asking the following question: "to what extent does a carbon price in this jurisdiction put our businesses at a competitive disadvantage relative to their rivals from other jurisdictions without a carbon price?"[97]

Eddy Isaacs, Scientific Advisory Committee Member of the Council of Canadian Academics, explained that a primary risk of uneven carbon compliance requirements lies in not being able to attract investment to the oil and gas sector in the face of increased carbon costs.[98]

Another risk raised by witnesses is that Canadian emissions-intensive firms, such as those in the oil and gas sector, facing increased carbon costs, could choose to leave Canada and move their businesses to jurisdictions with lower, or no, carbon prices. According to

Benjamin Dachis, C.D. Howe has found that among companies that decide to leave Canada because of higher carbon prices, about 90% of them go to the U.S.[99] If Canada reduces its GHG emissions only to have the businesses responsible for them leave Canada to go emit them elsewhere, that does no good for Canada or the climate. Under this scenario, the GHGs would still be emitted while Canada would lose out on productivity and employment.[100] The committee notes that according to the Organization for Economic Co-operation and Development (OECD) that Canada has among the lowest environmental taxes among the OECD member states.[101]

Several witnesses argued that because carbon pricing puts pressure on the oil and gas industry's international competitiveness, governments should design their carbon pricing systems to protect the industry. David Keane of BC LNG Alliance, for one, explained that LNG companies are not opposed to a carbon tax, but believe it is appropriate to provide compensating provisions or offsets to protect them from competition from other LNG exporters that are not subject to similar stringent carbon policies.[102] Likewise, Terry Abel, Executive Vice-President of the Canadian Association of Petroleum Producers, stressed that other countries with carbon pricing protect their emissions-intensive and trade-exposed industries and Canada should too. He noted:

> *Many jurisdictions across the world have adopted carbon policies, such as California in particular and the European Union, [that] already have policies that protect emission-intensive, trade-exposed industries. In the case of the hydrocarbon industry, California essentially provides 100 per cent protection of that industry from their carbon policies, and the European Union on average is somewhere in the 90 per cent range of protection.*[103]

Should the government introduce policy measures for the oil and gas sector to shelter it from the competitiveness risks associated with carbon pricing? How does Canada design programs that incent oil

In St. John's, Newfoundland and Labrador, the Senate Committee on Energy, the Environment and Natural Resources met with members and staff of the St. John's Board of Trade where some concerns were raised regarding the competitiveness of some of the industries they represent.

and gas industries to reduce emissions while protecting them from competition from jurisdictions with little to no carbon compliance requirements? How should the stringency of emission reduction measures be managed over time? Are there fairness and equity concerns that come with providing such policy support to one industry over another economic sector?

Canada has committed to phase out and rationalize inefficient fossil fuel subsidies. This was first announced at the September 2009 G20 summit in Pittsburgh and reaffirmed at the June 2016 North American Leader's Summit where Canada, the United States and Mexico committed to phase out inefficient fossil fuel subsidies by 2025.[104] Julie Gelfand, Commissioner of the Environment and Sustainable Development of the Office of the Auditor General of Canada told the committee that the federal government did not yet know the extent of non-tax measures that could be inefficient fossil fuel subsidies and that the "Department of Finance Canada did not have an implementation plan to support the phase-out and rationalization of tax measures that are inefficient fossil-fuel subsidies."[105] The committee is interested in the extent these subsidies may have assisted the oil and gas sector and whether these subsidies impede efforts to reduce emissions.

A carbon tariff on imported goods is a tool that governments may contemplate to level the carbon pricing playing field between countries. Mark Jaccard of Simon Fraser University told the committee that Canada does need climate-related tariffs, which are currently starting to be used in some jurisdictions in small amounts.[107] Jennifer Winter of the University of Calgary supported this, saying that "to level the playing field, in terms of taxing imports based on their emissions intensity, it could potentially work."[108] Ms. Winter cautioned however, that a tax on imports would affect Canadian consumers and that it would "not necessarily affect the companies that are exporting into Canada, and so it is an option to protect Canadian producers by making their costs internal in Canada, the same as firms that are external to Canada but that will be borne by Canadian consumers."[109]

Support for Industries under Carbon Pricing

Chris Ragan, Chair of Canada's Ecofiscal Commission explained that support under carbon pricing, either through exemptions or free-issuance of emission permits, can mitigate competitiveness concerns, but they should be *targeted, transparent and temporary*:

> They should be targeted to the sectors that need them, and that's really the energy-intensive and trade-exposed sectors. [...]
>
> They should be transparent [...] you should be explaining to the people why you are providing these [subsidies] to these emissions intensive sectors. [...]
>
> [They] should be temporary. If we [...] have a higher carbon price [than other jurisdictions], then we need to put these policies in place. But if they catch up to us, these policies can drop off, and that's why they should be temporary.[106]

Should the federal government consider levying tariffs on imported goods with high carbon content from places with low or no carbon emission reduction requirements?

Revenue Recycling and Complementary Measures

Several options were raised to the committee as to what can be done with carbon pricing revenues:

- Use carbon pricing revenues to reduce corporate and personal income taxes.[110] According to Chris Ragan of Canada's Ecofiscal Commission, reducing taxes would stimulate economic growth.
- Fund clean technology innovation to develop and deploy low-carbon solutions.[111]
- Provide transitional assistance to emissions-intensive and trade-exposed industries such as the oil and gas industry until trading partners adopt similar carbon pricing systems.[112]
- Provide assistance to lower-income households that may be negatively affected by carbon pricing.[113]
- Invest in government priorities like infrastructure projects or the reduction of public debt.[114]

B) Regulatory Measures

Regulations are another means to achieve carbon reductions. They can be used to supplement carbon pricing programs, particularly in situations where it is inefficient or impractical to apply a carbon price. For example, it is difficult to apply a carbon price to methane emissions because these emissions are hard to quantify since they arise from routine venting and accidental equipment leaks.[115]

Mark Jaccard characterized regulations as either being prescriptive, when they specify a compulsory measure – for example, a technology, process, or substance to be used or not used – or flexible, when they establish an outcome-based framework within which the regulated entity can choose the best approach for achieving targeted results.[116]

Mr. Jaccard explained that while governments can theoretically achieve their emission reduction goals through carbon pricing exclusively (up to $300 per tonne of CO_2e, as discussed above), it may prove difficult to gain and maintain public support due to the resulting increase in the cost of fossil fuels. [117] He noted that recent federal climate policy, such as the proposed federal methane regulations, is consistent with a regulatory approach to emission reductions.[118] Eric Meslin of the Council of Canadian Academies echoed Mr. Jaccard's point about public support for climate policy saying that "there should be a balance of flexible and stringent. We can't tell you the right balance; that's a policy decision [...] there are public expectations as well as public attitudes [...] recognize that it's a challenge that's [...] difficult to frame."[119]

According to Mr. Jaccard, should Canada adopt a flexible regulatory approach – as opposed to pure carbon pricing – that consisted of ramping up to a 2030 carbon price of about $40 as well as implementing a set of flexible regulations, like those discussed above, it could achieve GHG emission reduction cuts of 60%-80% by 2050.[120]

Alberta's *Climate Leadership Plan* is an example of what such flexible regulations can look like as it introduced two types of flexible regulations that are of note for the oil and gas sector (besides carbon pricing). The first is a legislated limit of a maximum of 100 Mt of CO_2e per year on the entire oil sands sector, which leaves about 30 Mt CO_2e left under the cap for

future oil sands emission growth. The second is a commitment to reduce methane emissions from oil and gas operations by 45% by 2025, in part through new emission design standards for new fa-cilities.

Another example of GHG emission regulation in the sector is how the Canada-Newfoundland and Labrador Offshore Petroleum Board regulates the daily and annual flaring allowances for offshore installations. Robert Cadigan of the Newfoundland and La-brador Oil & Gas Industries Association ex-plained that since 2006, the Board has initiated phased reductions in these allowances, keeping them at the lowest level.[121]

Terry Abel, Executive Vice-President of the Canadian Association of Petroleum Producers, stated that Canada's policies and regulations have pushed the oil and gas industry to innovate and invest in clean technology. He explained that "[b]ecause of the stringent environmental policies, our industry in Canada has constantly been pushing the envelope on cost-effective, environmentally responsible and lower emissions-intensive technology."[122]

Steve MacDonald, CEO of Emissions Reduction Alberta, asked: if Canada wants to allow risk-taking and experimentation to happen, should it apply the same regulatory environment to a prototype project as it would to a new refinery or extraction project? He recommended that governments create "regulatory sandboxes where we park some of the higher standard rules for a full-scale operation to allow the testing to happen."[123]

Finally, Timothy Egan, President of the Canadian Gas Association, explained how "cumbersome" the regulatory process is for developing new oil and gas projects.[124] He cautioned that "everyone who is looking at investing in extracted projects in this country is going to look at alternatives to invest in markets all around the world," and that Canada risks losing out on extractive development if investors judge that the country's regulatory system is too complex and lengthy.[125]

What is the best way to balance the need for stringent emission reduction regulations while maintaining a competitive environment to attract investment? Should the federal government rely on regulatory measures instead of carbon pricing to drive future emissions reductions?

Aad van Bohmen of the IEA told the committee that in order to avoid locking in long-lived emission-intensive infrastructure, policy and investment decisions should be made in consideration of an 80% emission reduction by 2050.[126] That being said, in-situ oil sands production, a relatively high emission extraction process, is projected to be the main area of growth in Canada's oil sector. As this report explores later in a section on technology options, there are some promising technology solutions that could significantly lower the emission intensity of in-situ production, possibly by as much as 80% of current emissions. While there are limits in how these technologies can be applied to existing in-situ operations, opportunities may exist for future projects to incorporate these technologies. *Would performance based regulations that require an emission intensity improvement on the order of up to 80% for new in-situ developments spur the deployment of these types of technologies?*

C) Federal Methane Regulations for Oil and Gas Sector

The federal government has committed to reduce methane emissions from the oil and gas sector by 40%-45% from 2012 levels by 2025 through regulatory measures. Methane has a higher radiative forcing potential than carbon dioxide. For example, it is 25 times more powerful than carbon dioxide in trapping heat in the atmosphere over a 100 year period.[127] This means that reducing methane emissions may be an effective approach in addressing climate change.

> *"The federal government has committed to reduce methane emissions from the oil and gas sector by 40%-45% from 2012 levels by 2025 through regulatory measures."*

In that context, the federal government published a technical backgrounder in May 2017 to describe its proposed outcome-focused regulations that would apply to oil and gas facilities responsible for the extraction, production, processing and transportation of crude oil and natural gas, including pipelines. The regulatory requirements would be applied in phases: the first requirements would be expected to come in force in 2020 with the rest of the requirements expected to be applied in 2023. The regulations will require oil and gas facilities to adopt a number of measures, including:

- the implementation of leak detection and repair programs;
- the conservation or destruction of gases (instead of venting) for all hydraulically-fractured wells; and
- the capture of gas by upstream oil and gas facilities to use it onsite, re-inject it underground, send it to a sales pipeline, or route it to a flare. [128]

It should also be noted that the federal government has committed to equivalency agreements with provinces and territories allowing regional approaches to replace federal regulations. Alberta and British Columbia already have methane venting regulations.

Although Canada and the U.S. share the same methane reduction target, Mr. Abel of the Canadian Association of Petroleum Producers

noted that Canada is already a high performer when it comes to methane reductions, more so when compared to the U.S.[129] Canada's position, compared to the United States, will only improve as the U.S. is expected to rescind or significantly revise its commitments regarding the reduction of methane emissions in the near future. Indeed, although the two countries jointly announced their commitment to cut methane emissions by 40%-45% during an official State visit by the Prime Minister to Washington, D.C. in March 2016,[130] the U.S. has since then proposed to temporarily suspend or delay certain requirements in its November 2016 methane rule designed to reduce the release of methane emissions from oil and gas operations on federal land.[131]

The federal government estimates that the compliance costs, net of the recovery of natural gas, of the proposed methane regulations will total $1.7 billion over 18 years.[132] When asked what impact the proposed relaxing of rules governing methane venting by the U.S. may have on Canada, John Moffet, Acting Associate Assistant Deputy Minister, Environment and Climate Change Canada, explained that the effect would be mitigated by the fact that emission venting is regulated at the state level in the U.S. and that "many states already have stated that they will continue to have methane requirements in place."[133]

TECHNOLOGY OPTIONS: WHAT WE HEARD

The history of Canada's oil and gas industry lies in the application of technology to create value from our resources. John Zhou described Alberta's oil sands as "technology oil." He said the following:

> *The oil sands and bitumen is technology oil. Twenty or thirty years ago, this resource was there, but we didn't gain anything from it. It's due to the technology, actually, that enabled us to produce bitumen to have a market value.*[134]

The committee was also told that the future of Canada's oil lies in innovation. The business imperative for oil and gas producers to seek efficiencies creates alignment between the goals of reducing costs and lowering emission intensity.[135] Mr. Zhou explained to the committee that "[i]nnovation is the key to this successful transition. The Canadian oil and gas sector is undergoing a transition to remain cost competitive and to become carbon competitive as well."[136]

Leah Lawrence, President and CEO of Sustainable Development Technology Canada, told the committee that a current key goal for oil sands innovation efforts is to improve the "well-to-wheels" emission intensity of bitumen to be on par with that of lighter oils, such as the conventional light oil that is produced offshore in Newfoundland and Labrador.[137] She explained that on a well-to-wheels basis, upstream oil and gas emissions account for about 11% of the total GHGs associated with the average barrel of oil; these are the emissions discussed in this report, and for which technology options are discussed below.

Eric Meslin, President and CEO of the Council of Canadian Academies, noted that "opportunities to reduce greenhouse gas emissions [in the oil sands] lie primarily with in situ operations." Likewise, Qi Liu, Scientific Director of the Institute for Oil Sands Innovation, explained that the current technology used to reduce the emissions related to oil sands production could be improved and that "[t]here is a better way to do it with low greenhouse gas emissions. We just haven't reached there yet. That is why it's still worthwhile to work on it."[138]

There are a lot of promising technologies that the committee heard about that could lower the GHG emission intensity of Canadian oil and gas, and probably lower costs too. For example, Eddy Isaacs of the Council of Canadian Academies, estimated that the application of commercial-ready energy efficiency technologies – such as co-generation of heat and power – could lead to an emission intensity improvement of about 20%-30% in the short term.[139]

With this potential improvement in mind, and as illustrated in Figure 16 on page 42, which shows that today's average in-situ barrel of oil contains 79 kg CO_2e per barrel, if in-situ emission intensity improves by 20%-30%, it would fall in the range of 55-63 kg CO_2e per barrel. This is on par with the 2015 emission

intensity of the average barrel of conventional oil.

Given the scale of the emission intensity challenge, there must also be a push for accelerated breakthroughs in transformative technologies. Steve MacDonald of Emissions Reduction Alberta argued that "meeting the world's growing energy demand while reducing GHG requires transformative technologies. Incremental improvements that allow us to do the same things better are essential, but they alone will not get us where we need to go."[140]

Should the federal government prioritize advancing commercial-ready technologies over supporting research and development for breakthrough technologies?

Soheil Asgarpour, President of the Petroleum Technology Alliance of Canada, laid out his organization's vision of four technology pathways to transition the oil and gas sector to a zero-carbon economy:

> *In transitioning the hydrocarbon sector to a zero-carbon economy by 2050, I envision the following key pathways. The first one, which would go to 2020, is about eco-efficient technologies, carbon capture, combined with CO_2 enhanced oil recovery and enhanced gas recovery, bitumen partial upgrading, development of steam generation, solar panels and solar technology to replace gas pneumatics.*
>
> *The second path is about low carbon bitumen production using artificial intelligence and also photonics, in-situ solvent in small gas-to-liquid units and conversion of CO_2 to methanol and methane.*
>
> *The third period, which is by 2040, is about zero bitumen emissions using application of new generation nuclear technology and application of genomics and nanotechnology.*
>
> *Finally, the period that goes to 2050 is about new products and a new model for green prosperity. It is about producing carbon fibres and graphene from bitumen, metal and rare earth elements recovery from tailings, hydrogen from oil and bitumen and over 300 value-added products that can be produced from a mega complex in Alberta.*[141]

The committee was told that there are no technological silver bullets, but that over time, if some of the technologies presented to the committee are deployed by oil and gas producers, major GHG reductions are possible.[142] Discussed below are some of the technologies to improve the emission intensity of oil and gas that were presented to the committee during its study. They are arranged according to Mr. Asgarpour's four pathways to help provide context for whether they can be considered near- or long-term solutions.

Pathway 1: Efficiency Technologies

- Energy efficiency: Some of the least expensive solutions to implement are efficiency-related and have the direct effect of lowering ongoing operation costs and GHG emissions. These technologies are mostly commercially-available.
- Co-generation: These technologies create useful heat and electricity together, as opposed to producing one or the other. For example, in-situ operations employing co-generation technology burn natural gas to produce steam while also generating

Committee members learned about new and upcoming clean technologies with representatives from the Newfoundland and Labrador Environmental Industry Association in St. John's, NL.

electricity to be used on-site, creating GHG emission reductions and cost savings. As well, co-generation leads to lower GHG emissions because the electricity it produces from natural gas is less emission-intensive than the coal- or diesel-fired electricity that it displaces.

- Solvent-assisted steam-assisted gravity drainage: By co-injecting trace amounts of a non-condensable gas like methane along with steam to produce in-situ oil, it reduces the need for additional steam to maintain reservoir pressure, thus lowering GHG emissions.[143]
- Carbon capture and utilization: CO_2 that is captured from industrial emission streams can be re-injected into already developed oil fields – this releases more oil from the partially-depleted well and sequesters the CO_2 in the underground formation. There is also potential beyond the short-term to use carbon capture technology on oil and gas facilities directly, where feasible.
- Clean power: Non-GHG emitting sources of electricity that displace natural gas-, diesel-, and coal-fired electricity help reduce the emission-intensity of production.
- Addressing fugitive emissions: The committee heard that commercially-ready technologies are available today that would have a significant impact on fugitive emissions associated with transporting natural gas.[144] In a pressurized pipeline system, there are many points where potent GHGs can be released, either on purpose or by accident, which are either detected or undetected. One technology solution, for example, is to replace natural gas-powered pneumatic instruments on pipeline systems with solar power ones, eliminating the need for venting in the operation of the equipment. Software and hardware for detecting leaks and pressure changes in a pipeline are another example of the types of technologies that could be deployed to address fugitive emissions.[145] Aad van Bohemen of the International Energy Agency called this the "low-hanging fruit" of Canada's GHG emission reduction options.[146]

Pathway 2: Low-Carbon Bitumen

- Solvents: Several witnesses were optimistic about the potential of solvents to significantly disrupt the future production methods of in-situ oil sands resources. As opposed to steam-assisted gravity drainage, which injects steam into sub-surface

bitumen to make it less viscous, non-aqueous solvents like butane or propane can be injected into the deposit to essentially dissolve the bitumen and lower viscosity without using steam. Witnesses told the committee that solvents have the potential to reduce GHG emission-intensity of in-situ oil by up to 80% compared to existing processes, while eliminating the use of water for extraction.[147] Steve MacDonald noted that the application of solvents would be focused on new exploration and development projects, as opposed to retrofitting existing facilities.[148] Solvents are an area of active research that is government-supported, but technologies need field testing before comercialization.[149]

- Partial upgrading: As the name suggests, partial upgrading takes bitumen and makes some improvements to its quality and market value. This has the effect of improving the environmental performance of bitumen products, as well as their economics, because the use of diluents for shipping bitumen in pipelines is reduced or eliminated. Partial upgrading has the potential to reduce GHG emissions by "up to 20% on a wheel-to-tank basis."[150] Partially upgraded bitumen is expected to increase pipeline capacity to move bitumen (since the amount of diluents is reduced) and be less costly to refine downstream.[151] Citing research from the University of Calgary's School of Public Policy, John Zhou estimated that for "every 100,000 barrels per day of bitumen partially upgraded, it can generate $3.5 billion labour income, $13.37 billion GDP and contribute $2.77 billion in revenue to the federal government and $1.85 billion in revenue to the provincial government over a 20 year period of time."[152] There are currently a number of government-supported bitumen partial upgrading technologies that are at the pilot and field demonstration stages.[153]
- Electromagnetic heating: Electricity is converted to electromagnetic radio waves, which are used to heat bitumen. These technologies are in the research and development stage.[154]
- Artificial intelligence: Advances in computers and artificial intelligence will provide many ways for oil and gas producers to streamline and optimize their operations, including by optimizing steam-to-oil ratios and managing reservoirs.[155]
- Photonics: Photonics applications – such as steam quality analysers, which can measure the flow rate, temperature, pressure, contaminants and moisture of steam – would allow in-situ operators to more efficiently operate steam generators, reducing GHG emissions and water use.[156]
- CO_2 chemical conversion: There are currently research efforts underway to determine processes by which CO_2 can be converted to other useful chemicals, such as methane or methanol.[157]

Pathway 3: Zero-Carbon Bitumen

- Small modular nuclear reactors: The potential for small nuclear reactors to produce GHG emission-free electricity has been touted as a potential power source for some oil sands facilities and processes; however, the potential demand for the technology may be limited if in-situ extraction moves away from steam-based extraction techniques.[158]
- Genomics: Genomics is the study of the genetic material within an organism. Scientists and researchers are examining the genetic material of microorganisms in the oil sands to understand and better manage microbial activities that could enhance recovery rates, accelerate remediation of water and tailings, and lower GHG emissions.[159]
- Nanotechnology: The potential uses for materials at the nano scale in the oil and gas industry could lead to entirely new ways to extract and process fossil fuel products.

This is an active area of research in lab settings.[160]

Pathway 4: Bitumen Beyond Combustion

- According to John Zhou, Vice President of Clean Energy at Alberta Innovates, "bitumen beyond combustion" is "a new concept and a long-term strategy for Canadian oil sands. Many believe that oil will hit its peak before or by the middle of this century. Bitumen as a fuel commodity will face even greater challenges by that time. Through bitumen beyond combustion (BBC), innovative technologies are sought to make value-added materials from bitumen. BBC takes advantage of the large molecules in bitumen. Hydrogen in bitumen may provide the energy required for the conversion, making the entire value-added process emissions-free." In a written submission to the committee, Mr. Zhou highlighted some potentially valuable products that could be created through bitumen conversion, including asphalt, carbon fibres, polycarbonate, polyurethane, adhesives, coatings, composites, activated carbon and graphene.[161]

Should the federal government adopt and communicate a vision of a technology pathway that reconciles the role of upstream oil and gas production with the low-carbon economy of the future?

TECHNOLOGY DEPLOYMENT CHALLENGES: WHAT WE HEARD

As shown in Table 4, the majority of Canadian energy research, development and demonstration (RD&D) funding (both public and private) is aimed at fossil fuel supply technologies. Fossil fuel supply RD&D is driven much more by private investment than by public investment compared to other energy RD&D categories: the ratio of private-to-public RD&D investment for fossil fuel technologies is 4:1, compared to 1:1.4 for renewable and clean energy supply RD&D and 1.1:1 for energy end use RD&D.[162] Witnesses characterized Canada's clean technology RD&D capacity as excellent at the early stages of the innovation cycle that is doing basic research and developing and testing ideas. That said, they expressed concern regarding the later stages, where innovation leads to new patents, commercialization and the deployment of clean technologies.[163] In effect, there is a comercialization gap, where the take up and adoption of clean technologies in upstream oil and gas projects takes a very long time. In that regard, the committee heard that it can take up to 30 years for new technologies to penetrate in the sector.[164]

As Terry Abel of the Canadian Association of Petroleum Producers explained, "the big challenge in a lot of cases is not the tabletop

Table 4 – Energy Research, Development and Demonstration Funding, Canada

	Federal (2014/15)	Provincial (2014/15)	Industry (2013)
	($millions)		
Fossil fuels supply (including carbon capture and storage)	99	274	1,532
Renewable and clean energy supply	217	167	273
Energy end use	100	79	197
Total energy RD&D	**416**	**520**	**2,001**

Source: NRCan Energy Fact Book 2016-17

research and development work. It is taking some of those ideas and moving them into the field. When you're moving those research projects to commercialization, it's in the hundreds of millions of dollars of investment to actually take a technology and make it commercial."[165]

> *"The challenge of getting technology deployed in the sector is multi-faceted and complex."*

The challenge of getting technology deployed in the sector is multi-faceted and complex. Soheil Asgarpour, President of Petroleum Technology Alliance of Canada, highlighted some of the main innovation challenges that the industry faces:

> *The main innovation challenges our industry currently faces include great basic research that fails to advance post-publication; focus on technology push rather than market pull; lack of funding and access to sites for field demonstration of SME technologies; slow market uptake of technologies; lack of interest from venture capital to invest in clean technology; the slow advancement of technology movement from concept to commercialization; and, finally, lack of infrastructure within small producers to adopt new technologies.*[166]

Leah Lawrence, President and Chief Executive Officer of Sustainable Development Technology Canada explained to the committee that small- and medium-sized technology companies (SMEs) are hard-pressed to sell their innovations in the oil and gas sector because of technology risk compounded by finance risk.[167] She called it a "chicken and egg" problem, where firms have financed and de-risked their technologies up to the pre-commercialization stage, but are unable to sell their technologies to large Canadian and international oil and gas companies until they prove a field-scale or commercial-scale demonstration.[168]

The committee was told that SMEs are unable to attract investment for such demonstration projects. As Steve MacDonald explained, "access to capital is a significant challenge [...] we simply do not have access to the level of large patient capital that is required to move some promising technologies to commercialization. We need broader and deeper financial markets to reduce the costs of financing low carbon innovations."[169]

That said, deploying clean technology in the oil and gas sector is about more than just invention and financing; according to Mr. MacDonald it is "also the entire suite of tools that include policy, regulatory, program, and the business innovation required to successfully deploy new technologies."[170]

For example, Alberta's forthcoming methane reduction regulations were praised for the opportunities that they will create for companies to deploy technology solutions. Mark Salkeld of the Petroleum Services Association of Canada described how the policy would affect his organization's members:

> *There is a good percentage of our membership that is very keen to identify these opportunities, to be first movers in methane emissions reductions software for tracking it so that we can track it [...] That's the kind of technology we're getting into because it's*

> *taking the federal government's 45 per cent reduction over 2014 emissions [...]. We have member companies excited about developing the software that can measure that, not just on that broad scope but to be able to report back right at the field level, right at the well site, how we have come up with ideas to measure the greenhouse gases or measure the methane emissions and then reduce them and measure that.*[171]

Mark Jaccard noted that both carbon pricing or flexible regulations can create an incentive for firms to adopt cleaner technologies.[172] Terry Abel of the Canadian Association of Petroleum Producers echoed this argument, telling the committee:

> *We're more committed than any other part of the world to developing technologies. Absolutely that's based on very stringent environmental regulation within this country. We invest that technology to allow us to perform in an environmentally responsible manner that conforms with the regulations in Canada and still allows us to be competitive on the world market.*[173]

Steve MacDonald, of Emissions Reduction Alberta, explained to the committee that "the only way to succeed is to partner."[174] Witnesses described a myriad of relationships between industry, government, and academia in the oil and gas innovation ecosystem. Key players include Canada's Oil Sands Innovation Alliance (COSIA), Petroleum Technology Alliance of Canada, Institute for Oil Sands Innovation, Sustainable Development Technology Canada, Natural Resources Canada, National Research Council, Natural Gas Technologies Centre, and Emissions Reduction Alberta among others. In part, these organizations depend on government funding for support, but as witnesses noted, government dollars tend to leverage private dollars multiple times over.[175] As well, COSIA, which includes the largest oil sands producers, has invested $1.33 billion to develop 936 distinct technologies aimed at improving tailings management and reducing the impacts on air, land and water, and they currently have many projects that show potential in helping reduce emissions.

For oil and gas companies looking at adopting a new clean technology for an existing or proposed project, cost is just one concern that needs to be balanced against others. When GHG emissions are priced, the expected performance of GHG reducing technologies helps firms avoid carbon costs, but the economics matter when choosing least-cost technology options that improve performance.

For oil and gas companies looking at adopting a new clean technology for an existing or proposed project, cost is just one concern that needs to be balanced against others.

There are also issues with industry awareness of clean technology solutions that could be used if companies knew about them. Soheil Asgarpour said that, recognizing this information gap, the Petroleum Technology Alliance of Canada was working to educate its members in terms of what technology is available.[176] Leah Lawrence explained that large oil and gas companies prefer not to be the first-adopters of new technologies and prefer to rely on proven technologies.[177] Mark Jaccard acknowledged that being "first" comes

at a higher price, but that cost projections for new technologies are often multiple times higher than they become over time as firms learn how to effectively integrate and deploy them.[178]

How can Canada address the commercialization gap that is preventing innovative companies from getting their technology solutions that reduce GHGs to market? What policy and regulatory frameworks best support an investment climate that will enable innovators to raise capital and test their technologies? What strategic partnerships should be strengthened and leveraged in order to accelerate the development of breakthrough technologies that will be needed to grow the oil and gas industry in a carbon-constrained world? Is there a role for the federal government in de-risking the development and deployment of clean technology solutions?

MOVING FORWARD

Modern society currently runs on oil and gas. It fuels our transportation, heats our buildings, generates electricity, and it runs our machinery. Petroleum is used for non-energy uses such as clothing materials, pharmaceutical products, asphalt, chemicals, plastics and other synthetic materials. Transitioning away from carbon-based fuels will require a dramatic shift in how energy is used in society.

The upstream oil and gas sector is an emissions-intensive sector with few easy solutions for adapting to a carbon-constrained world. There are technology options being developed that could significantly lower the emissions of future oil and gas projects, and which could incrementally lower emissions for current projects, if they are deployed; however, as unconventional resources increase as a share of total production, the trend suggests that emissions from the sector will rise in the absence of emission performance improvements.

The committee heard how innovators are rising to the challenge, through many promising research and development partnerships as well as concrete opportunities for reducing the emission intensity within the Canadian oil and gas sector. Already, in-situ emission intensity has improved by 35% from 1990 levels; but this will not lead to the emission reductions that are required to achieve Canada's national targets. Breakthrough technologies are needed to break from the current trend and enable substantial GHG emission reductions from oil and gas production. Oil and gas technologists have described lower-carbon pathways that envision a future where the sector grows while reducing emissions.

Existing oil and gas emissions are largely locked-in due to technical constraints and the long-lived nature of oil and gas projects. Depending on the stringency of carbon policies, it could be a while before emissions in the sector align with national emission reduction targets, but with incremental improvements, existing projects can at least lower emissions to a level that is perhaps in line with other economic sectors, a necessary step given the immense costs of GHG emissions. Methane is

25 times more powerful than carbon dioxide in trapping heat in the atmosphere, thus reducing fugitive methane emissions may have a large impact in addressing climate change. Increased investment in and deployment of clean technologies would bring not just environmental benefits, but also improve the sector's competitiveness.

Julie Gelfand, Commissioner of the Environment and Sustainable Development told the committee that Canada missed opportunities in not pursing commitments to introduce oil and gas emission reductions. This will likely contribute to the country not meeting its 2020 emission target (17% below 2005 levels by 2020).

There are actions all governments can take to spur this transition. Some witnesses supported carbon pricing mechanisms as a policy tool to reduce emissions by incentivizing clean technology investment and deployment, but with caveats. First, a carbon price that is too low will not send the right market signal to producers; on the other hand, a price that is too high could chase away investment if other jurisdictions do not also price carbon. There are remedies for this, but governments must choose solutions that satisfy their particular circumstances and policy goals. Second, achieving Canada's emission reduction goals with carbon pricing alone would require such high carbon prices that this approach may not find much support among Canadians. This suggests that governments may want to adopt a less-efficient, but more practical mix of carbon pricing and complementary policies to achieve the same end. However, would this be less transparent because regulations carry implicit costs that are not necessarily apparent to consumers? It will be important to consider how climate policies interact – and how different policies in different jurisdictions can create sub-optimal outcomes – necessitating coordination between governments.

APPENDIX A – LIST OF WITNESSES

March 22, 2016	
Environment and Climate Change Canada	Dan McDougall, Assistant Deputy Minister, Strategic Policy Branch Derek Hermanutz, Director General, Economic Analysis Directorate, Strategic Policy Branch Mike Beale, Assistant Deputy Minister, Environmental Stewardship Branch
April 12, 2016	
National Energy Board	Jim Fox, Vice President, Integrated Energy Information and Analysis Shelley Milutinovic, Chief Economist
April 14, 2016	
Natural Resources Canada	Jeff Labonté, Director General, Energy Safety and Security Niall O'Dea, Director General, Electricity Resources Branch Marc Wickham, Director, Science and Technology Programs, Innovation and Energy Technology Sector, Office of Energy Research and Development Drew Leyburne, Director General, Energy Policy Branch Patricia Fuller, Director General, Office of Energy Efficiency Paula Vieira, Director, Transportation and Alternative Fuels Division Laura Oleson, Director, Demand Policy and Analysis, Office of Energy Efficiency, Energy Sector Debbie Scharf, Director, Equipment Division
April 19, 2016	
Canadian Council on Renewable Electricity	Jacob Irving, President, Canadian Hydropower Association
April 21, 2016	
Canadian Nuclear Association	John Barrett, President and Chief Executive Officer

May 3, 2016	
Ecologic Institute US	Max Gruenig, President
TransAlta Corporation	Don Wharton, Managing Director for Carbon Transition
May 5, 2016	
Canadian Electricity Association	Sergio Marchi, President and CEO Devin McCarthy, Director, Generation and Environment
Capital Power	Martin Kennedy, Vice President, External Affairs
Nova Scotia Power Inc.	Terry Toner, Director, Environmental Services
Canadian Biogas Association	Jennifer Green, Executive Director Kevin Matthews, Director Donald Beverly, Director
May 10, 2016	
As an individual	Andrew Leach, Associate Professor, Alberta School of Business, University of Alberta Mike Cleland, Senior Fellow, University of Ottawa
HEC Montréal	Pierre-Olivier Pineau, Professor, Chair in Energy Sector Management
May 12, 2016	
Association of Major Power Customers of BC	Brian Wallace, Counsel Carlo Dal Monte, Director, Energy, Catalyst Paper Corporation Karina Brino, President and CEO, Mining Association of BC
May 17, 2016	
SaskPower	Mike Marsh, President and Chief Executive Officer Guy Bruce, Vice President, Planning, Environment and Sustainable Development
BC Hydro	Chris Sandve, Director of Policy and Reporting
May 19, 2016	
Transport Canada	Ellen Burack, Director General, Environmental Policy Jim Lothrop, Director General, Sustainable Transportation Stewardship

May 31, 2016	
National Airlines Council of Canada	Marc-André O'Rourke, Executive Director Teresa Ehman, Chair, Environment Subcommittee
Green Aviation Research and Development Network	Sylvain Cofsky, Executive Director Fassi Kafyeke, Senior Director, Strategic Technology and Advanced Product Development, Bombardier Aerospace
June 2, 2016	
Ontario Power Generation	Jeff Lyash, President and Chief Executive Officer
NB Power	Neil Larlee, Director, Strategic Planning
June 9, 2016	
Canadian Hydrogen and Fuel Cell Association	Eric Denhoff, President and Chief Executive Officer
Renewable Industries Canada	Andrea Kent, President
Canadian Automated Vehicles Centre of Excellence	Barrie Kirk, Executive Director
September 27, 2016	
Association of Canadian Port Authorities	Wendy Zatylny, President Debbie Murray, Director, Policy and Regulatory Affairs
Conference Board of Canada	Louis Thériault, Vice President, Public Policy
September 29, 2016	
Canadian Natural Gas Vehicle Alliance	Bruce Winchester, Executive Director
Pollution Probe	Steven McCauley, Acting Chief Executive Officer
October 18, 2016	
Electric Mobility Canada	Chantal Guimont, President and Chief Executive Officer
Canadian Trucking Alliance	Jonathan Blackham, Policy and Government Affairs Assistant
October 20, 2016	
Coal Association of Canada	Robin Campbell, President
October 25, 2016	
VIA Rail Canada	Yves Desjardins-Siciliano, President and Chief Executive Officer Pierre Le Fèvre, Senior Advisor to CEO and Chief Executive Officer Bruno Riendeau, Director, Safety and Environment

Railway Association of Canada	Michael Bourque, President and Chief Executive Officer Michael Gullo, Director, Policy, Economic and Environmental Affairs
October 27, 2016	
Canadian Vehicle Manufacturers' Association	Mark Nantais, President
Fertilizer Canada	Garth Whyte, President and Chief Executive Officer Clyde Graham, Senior Vice President
November 1, 2016	
Canadian Manufacturers & Exporters	Mathew Wilson, Senior Vice President, National Policy Nancy Coulas, Director, Energy and Environment Policy
CMC Research Institutes, Inc.	Richard Adamson, President
November 3, 2016	
Canadian Urban Transit Association	Alex Maheu, Director, Public Affairs Jeff Mackey, Policy Analyst
Hydro-Québec	Louis Beauchemin, Senior Director, Subsidiary Management France Lampron, Director, Transportation Electrification
November 24, 2016	
Sustainable Development Technology Canada	Leah Lawrence, President and Chief Executive Officer
Alberta Innovates	John Zhou, Vice President, Clean Energy
November 29, 2016	
C.D. Howe Institute	Benjamin Dachis, Associate Director, Research
December 1, 2016	
PTAC Petroleum Technology Alliance Canada	Soheil Asgarpour, President
December 6, 2016	
Council of Canadian Academies	Eric M. Meslin, President and Chief Executive Officer Eddy Isaacs, Scientific Advisory Committee Member
In Situ Oil Sands Alliance	Richard Sendall, Chairman Patricia Nelson, Vice Chair

December 8, 2016	
Federation of Canadian Municipalities	Clark Somerville, President Dallas Alderson, Manager, Policy and Research
As an individual	Mark Jaccard, Professor, Simon Fraser University
December 13, 2016	
Canada West Foundation	Trevor McLeod, Director of the Centre for Natural Resources Policy
December 15, 2016	
Canadian Energy Research Institute	Allan Fogwill, President and Chief Executive Officer
January 31, 2017	
Global CCS Institute	Jeff Erikson, General Manager, Americas Region
February 2, 2017	
Institute for Oil Sands Innovation	Qi Liu, Scientific Director
Emissions Reduction Alberta	Steve MacDonald, Chief Executive Officer
February 16, 2017	
Canada Mining Innovation Council	Carl Weatherell, Executive Director and Chief Executive Officer
As an Individual	Jennifer Winter, Assistant Professor, School of Public Policy, University of Calgary
February 28, 2017	
Chemistry Industry Association of Canada	Bob Masterson, President and Chief Executive Office David Podruzny, Vice-President, Business and Economics
Petroleum Services Association of Canada	Mark A. Salkeld, President and Chief Executive Officer
March 2, 2017	
Forest Products Association of Canada	Robert Larocque, Vice President, Climate Change, Environment and Labour Kate Lindsay, Director, Environmental Regulations and Conservation Biology
Mining Association of Canada	Brendan Marshall, Vice President, Economic and Northern Affairs
March 9, 2017	
Canadian Steel Producers Association	Joseph Galimberti, President
March 28, 2017	
Aluminium Association of Canada	Jean Simard, President and Chief Executive Officer

March 30, 2017	
Cement Association of Canada	Michael McSweeney, President and Chief Executive Officer Adam Auer, Vice-President, Environment and Sustainability
Canada's Ecofiscal Commission	Chris Ragan, Chair
April 6, 2017	
Environment and Climate Change Canada	John Moffet, Acting Associate Assistant Deputy Minister, Environmental Protection Branch Derek Hermanutz, Director General, Economic Analysis Directorate, Strategic Policy Branch Matt Jones, Director General, Climate Policy Office, Strategic Policy Branch Helen Ryan, Director General, Energy and Transportation, Environmental Protection Branch
Department of Finance Canada	Sean Keenan, Director, Sales Tax Division, Tax Policy Branch Gervais Coulombe, Chief, Sales Tax Division, Tax Policy Branch
April 11, 2017	
Shell Canada	Tim Wiwchar, Portfolio Business Opportunity Manager
Big Moon Power	Lynn Blodgett, President and Chief Executive Officer Jamie MacNeil, Country Manager
April 13, 2017	
Canadian Gas Association	Timothy M. Egan, President and Chief Executive Officer
The Canadian Chamber of Commerce	Katrina Marsh, Director, Environment and Natural Resources Policy

May 11, 2017	
International Energy Agency	Tim Gould, Head of Energy Supply Outlook Division Jean-François Gagné, Head of Energy Technology Policy Division Sylvia Bayer, Country Desk Officer in the Energy Policy and Security Division Aad van Bohemen, Head of Energy Policy and Security Division Peter Fraser, Head of Gas, Coal and Power Division
June 8, 2017	
Newfoundland and Labrador Oil & Gas Industries Association	Robert Cadigan, President and Chief Executive Officer
Canadian Association of Petroleum Producers	Terry Abel, Executive Vice-President Patrick McDonald, Director, Climate and Innovation
June 15, 2017	
Canadian Labour Congress	Donald Lafleur, Executive Vice-President Chris Roberts, Director, Social and Economic Policy
Canadian Fuels Association	Peter Boag, President and Chief Executive Officer Lisa Stilborn, Vice-President, Ontario Division
September 19, 2017	
Natural Resources Canada	Martin Gaudet, Deputy Director, Housing Division, Office of Energy Efficiency, Energy Sector Dean Haslip, Director General, CanmetENERGY-Ottawa, Innovation and Energy Technology Sector Sarah Stinson, Director, Buildings and Industry Division, Office of Energy Efficiency, Energy Sector
September 21, 2017	
Canada Mortgage and Housing Corporation	Duncan Hill, Manager, Housing Needs Research
CSA Group	Michael Leering, Director, Environment and Business Excellence Dwayne Torrey, Director, Construction and Infrastructure

September 26, 2017	
As an Individual	Ian Beausoleil-Morrison, Professor, Faculty of Engineering and Design, Carleton University
Canadian Association for Renewable Energies	Bill Eggertson, Executive Director
September 28, 2017	
As an Individual	James Tansey, Executive Director, Centre for Interactive Research on Sustainability, University of British Columbia
October 3, 2017	
Canadian Construction Innovations	Pierre Boucher, President Jim Ilkay, Senior Partner, Innovia Corporation
Canadian Home Builders' Association	Kevin Lee, Chief Executive Officer
October 5, 2017	
BC LNG Alliance	David Keane, President and Chief Executive Officer
The Conference Board of Canada	Louis Thériault, Vice-President, Industry Strategy and Public Policy
October 17, 2017	
Public Services and Procurement Canada	Kevin Radford, Assistant Deputy Minister, Real Property Branch Veronica Silva, Director General, Technical Services
Treasury Board of Canada Secretariat	Taki Sarantakis, Associate Secretary Nick Xenos, Executive Director, Centre for Greening Government
October 19, 2017	
National Research Council Canada	Michel Dumoulin, Acting Vice-President, Engineering Philip Rizcallah, Director, Research and Development, Construction
Canada Green Building Council	Thomas Mueller, President and Chief Executive Officer
October 24, 2017	
Federation of Canadian Municipalities	Brock Carlton, Chief Executive Officer Matt Gemmel, Policy Advisor

Canadian Propane Association	Nathalie St-Pierre, President and Chief Executive Officer Greg Thibodeau, Manager, Marketing, Pembina Pipeline Corporation Guy Marchand, President and Chief Executive Officer, Budget Propane 1998 Inc. Taylor Granger, Business Development Leader, SLEEGERS Engineered Products Inc.
October 26, 2017	
BOMA Canada	Benjamin L. Shinewald, President and Chief Executive Officer
Engineers Canada	David Lapp, Practice Lead, Globalization and Sustainable Development
Royal Architectural Institute of Canada	Bruce Lorimer, Interim Executive Director Emmanuelle van Rutten, Regional Director, Ontario North, East and Nunavut
November 2, 2017	
Insurance Bureau of Canada	Nadja Dreff, Director, Economics and Assistant Chief Economist Craig Stewart, Vice-President, Federal Affairs
December 7, 2017	
Office of the Auditor General of Canada	Julie Gelfand, Commissioner of the Environment and Sustainable Development David Normand, Director Elsa DaCosta, Director Doreen Deveen, Director
February 8, 2018	
As an Individual	Blair Feltmate, Head, Intact Centre on Climate Adaptation, University of Waterloo
Canadian Energy Efficiency Alliance	Philippe Dunsky, Vice-Chair Martin Luymes, Chair
February 15, 2018	
As an Individual	Warwick F. Vincent, Full Professor, Centre for Northern Studies, Laval University
QUEST	Brent Gilmour, Executive Director Tonja Leach, Managing Director

March 1, 2018	
Ecovert Sustainability Consultants	Jim Lord, Founding Principal
Yukon Housing Corporation	Pamela Hine, President
Government of the Northwest Territories	Tom R. Williams, President and Chief Executive Officer, Northwest Territories Housing Corporation
Nunavut Housing Corporation	Gary Wong, Director of Infrastructure Stephen Hooey, Chief Operating Officer
March 22, 2018	
Energy Services Association of Canada	Stuart Galloway, Chief executive Officer
March 27, 2018	
City of Toronto	Jim Baxter, Director, Environment and Energy Division Mary-Margaret McMahon, Councillor
City of Halifax	Maggie MacDonald, Managing Director, Government Relations and External Affairs Shannon Miedema, Energy and Environment Program Manager, Planning and Development
March 29, 2018	
Canadian Real Estate Association	Dina McNeil, Director of Government Relations Dil Puar, Manager of Government Relations
Heating, Refrigeration and Air-conditioning Institute of Canada	Warren Heeley, President Martin Luymes, Director, Programs and Relations Bruce Passmore, Board Chair
Canada Mortgage and Housing Corporation	Luisa Atkinson, Director, First Nation Housing
Crown-Indigenous Relations and Northern Affairs	Mark Hopkins, Director General, Natural Resources and Environment Branch, Northern Affairs Organization
Indigenous Services Canada	Lyse Langevin, Director General, Community Infrastructure Branch, Regional Operations
April 17, 2018	
Fraser Institute	Kenneth P. Green, Senior Director, Natural Resource Studies
Clean Energy Canada	Dan Woynillowicz, Policy Director, Morris J. Wosk Centre for Dialogue, Simon Fraser University

April 19, 2018	
Smart Prosperity Institute	Stewart Elgie, Co-Chair William Scott, Research Associate
April 26, 2018	
Natural Resources Canada	André Bernier, Senior Director, Electricity Resources Branch, Energy Sector Dean Haslip, Director General, CanmetENERGY-Ottawa Joyce Henry, Director General, Office of Energy Efficiency, Energy Sector Terry Hubbard, Director General, Petroleum Resources Branch, Energy Sector John Kozij, Director General, Canadian Forest Service Amanda Wilson, Director General, Office of Energy Research and Development, Innovation and Energy Technology Sector

APPENDIX B – FACT FINDING MISSIONS – LIST OF WITNESSES

Western Canada – October 2-7, 2016 (Vancouver, Kitimat and Prince George, British Columbia, Calgary, Alberta and Estevan, Saskatchewan)	
Alberta Electric System Operator	Miranda Keating Erickson, Vice President Operations Angela Anderson, External Relations Advisor
ARC Financial Corp	Peter Tertzakian, Chief Energy Economist and Managing Director
Canada's Oil Sands Innovation Alliance	Dan Wicklum, Chief Executive Officer
Canfor Pulp Ltd	Martin Pudlas, Vice President, Operations Peter Lovell, General Manager Robert Thew, Manager, Strategic Capital and Energy
CanmetENERGY	Cécile Siewe, Director General, Devon Research Center Jinwen Chen, Director, Hydrocarbon Conversion Michael Layer, Senior Program Manager
Legislative Assembly of Saskatchewan	Lori Carr, Member of the Legislative Assembly
Pembina Institute	Chris Severson-Baker, Managing Director
Petroleum Technology Research Centre	Norm Sacuta, Communications Manager
Powertech Laboratories	Madhvi Ramnial, Manager, Client Engagement and Business Development Angela Das, Senior Manager, Advanced Transportation Jeff Turner, Project Manager, Electric Vehicles and Energy Systems David Facey, Legal Counsel Frankie Nash, Policy Analyst

Rio Tinto	Blair Dickerson, Vice President Richard Prokopanko, Director of Government Affairs Gareth Manderson, General Manager Kevin Dobbin, Manager Communications and Communities, BC Works Manny Arruda, Casting Coordinator, BC Works Alain Bouchard, Business Partner HSE Graham Caven, Reduction PTA Trainer, BC Works Carolyn Chisholm, Principal Advisor, Vice President Canada Office Marion Egan, Executive Assistant, BC Works Joe Velho, Coordinator, BC Works
SaskPower	Howard Matthews, Vice President, Power Production Sandra Beingessner, Executive Co-ordinator, Executive Offices Dave Jobe, Director, Carbon Capture and Storage Mike Zeleny, Tour Ambassador, Carbon Capture and Storage
Seven Generations Energy Ltd	Alan Boras, Director, Communications and Stakeholders Relations
University of Calgary	Dan McFadyen, Program Director, School of Public Policy Robert Mansell, Academic Director, School of Public Policy Shantel Jordison, Manager, Extractive Resource Governance Program
University of Northern British Columbia	Daniel Weeks, President Daniel Ryan, Interim Vice President, Academic and Provost Geoffrey Payne, Interim Vice President, Research Tim Tribe, Vice President, Advancement Robert Knight, Vice President, Finance and Business Operations Chris Buse, CIRC Project Lead

	Stephen Déry, Canada Research Chair in Northern Hydrometeorology Kevin Ericsson, Chief Engineer David Claus, Assistant Director, Facilities Management
Vancouver Fraser Port Authority	Duncan Wilson, Vice President, Corporate Social Responsibility Carrie Brown, Director, Environmental Programs Evangeline Englezos, Director, Community and Aboriginal Affairs Christine Rigby, Environmental Specialist, Air Emissions
Ontario – November 14-17, 2016 (Sarnia and Hamilton, Ontario)	
ArcelorMittal Dofasco	Sean Donnelly, President and Chief Executive Officer Tony Valeri, Vice President, Corporate Affairs Henry Wegiel, Director, Trade and Government Relations Ian Shaw, Manager, Energy Management Jim Stirling, General Manager, Environment Richard Do Couto, Specialist, Corporate Responsibility Tom Kuhl, General Manager of Primary Manufacturing Technology Dan Evans, Reliability Coach Errol Hilado, Process Reliability Specialist
BioAmber	Mike Hartmann, Executive Vice President Ann Waddell, Vice president, Government Affairs Fabrice Orecchioni, Chief Operations Officer
Bioindustrial Innovation Canada	Sandy Marshall, Executive Director
Biox Corporation	Alan Rickard, Chief Executive Officer Courtney Quinn, Vice President, Finance Ryan Doell, Operations Manager Bozena Millivojevic, Production Manager

Canadian Fuels Association	Lisa Stilborn, Vice President, Ontario Division Erin Brophy, Communications Manager
CanmetMATERIALS	Philippe Dauphin, General Manager Mark S. Kozdras, Program Manager, Automotive Materials Hitesh Jain, Manager, Business and Contracts
Chemistry Industry Association of Canada	Bob Masterson, President and Chief Executive Officer David Podruzny, Vice President, Business and Economics Erika Adams, Director, Communications
City of Hamilton	His Worship Fred Eisenberger, Mayor Andrew Grice, Director, Water and Wastewater Operations Geoff Lupton, Director, Energy, Fleet and Traffic John Mater, Director, Corporate Assets and Strategic Planning Dan Chauvin, Director, Woodward Upgrades Dan McKinnon, General Manager, Public Works Mark Bainbridge, Acting Director, Hamilton Water Greg Crone, Strategic Initiatives and Policy Advisor Frank Gazzola, Superintendent, Energy Engineering Plamen Nikolov, Senior Project Manager, Capital Works
Imperial	Brian M. Fairley, Sarnia Refinery Manager George E. Vincent, Senior Regulatory Affairs Advisor Dave Luecke, Sarnia Chemical Plant Manager Jon Harding, Community Affairs and Aboriginal Relations Advisor

McMaster University	Ishwar Puri, Dean Faculty of Engineering Rob Baker, Vice President Research Nick Markettos, Acting Director, McMaster Institute for Transportation and Logistics Altaf Arain, Director, McMaster Centre for Climate Change Gillian Goward, Acting Associate Dean Research and External Relations Lori Dillon, Manager, Research Communications Alex Lawson, Executive Advisor, Public Affairs Kristen Munro, Manager, Public Affairs Ali Emadi, Director of MacAUTO Saeid Habibi, Professor, Mechanical Engineering Megan Wood, Team Lead, McMaster Engineering EcoCAR3 Team Theo Abraham, Communications Manager, McMaster Engineering EcoCAR3 Team
NOVA Chemicals	Rob Thompson, Regional Manufacturing Director Ken Faulkner, Director of Government Relations Meaghan Kreeft, Communications Consultant
Sarnia-Lambton Chamber of Commerce	Shirley de Silva, President and Chief Executive Officer Monica Shepley, Manager of Advocacy and Policy Development Mark Lumley, Chairman, Board of Directors Michael Kooy, 1st Vice Chair Peter Smith, Co-Chair, Energy Committee Alex Palimaka, Board Member Cathy MacLellan, Vice President Human Resources and Outreach, Ubiquity Solar Ed brost, President, Je&M Consulting Ltd. Maike Luiken, Bluewater Technology Access Centre

	Joe Lasowski, CF Industries
Sarnia-Lambton Economic Partnership:	George Mallay, General Manager.
Shell	Helen Bennett, Emerging Regulatory Policy Issue Advisor
Union Gas	Sarah Van Der Paelt, Director, Distribution Business Development and Strategic Accounts
Suncor Energy	Michael Kandravy, Director, Fuels Quality and Regulatory Affairs Michael Southern, Manager, Government Relations
Western Sarnia-Lambton Research Park	Tom Strifler, Executive Director Katherine G. Albion, Commercialization Centre Director Victoria Townsend, Research Engineer and Project Manager Stephen Reaume, Coordinator Mike Nesdoly, Manager, Applied Research and Innovation
Quebec – February 7-8, 2017 (Montreal and Varennes, Quebec)	
AQPER (Association québécoise de la production d'énergie renouvelable)	Jean-François Samray, President and Chief Executive Officer
CanmetENERGY	Gilles Jean, Managing Director Lisa Dignard, Director, Integration of Renewable and Distributed Energy Resources R&D Program Éric Soucy, Director, Industry R&D Program Chantal LeRoy, Acting Director, Building R&D Program Amélie Richard, Commercialisation Officer
City of Laval	Stéphane Boyer, City Councillor Ian Dessureault, Environment Services
Écotech Québec	Denis Leclerc, President and Chief Executive Officer Marie-Hélène Labrie, Vice-President of the Board Élise Laferrière, Vice-Presidente, Partnerships and Operations

Gaz Métro	Stéphanie Trudeau, Principal Vice-President, Regulations, Clients and Communities Frédéric Krikorian, Director, Sustainable Development, Public and Governmental Affairs
Hydro-Québec's Research Institute	Jérôme Gosset, Director Jean-Pierre Tardif, Advisor – Communications and Marketing
McGill	Jim Nicell, Professor & Dean of Engineering Subhasis Ghoshal, Director, Trottier Institute for Sustainability in Engineering and Design Lauren Penney, Manager, Trottier Institute for Sustainability in Engineering and Design Benoit Boulet, Associate Dean, Research & Innovation François Bouffard, Associate Professor Yixin Shao, Professor Jeff Bergthorson, Associate Professor
Union des producteurs agricoles	Pierre Lemieux, Second Vice-President Daniel Bernier, Research and Agricultural Policy Advisor – Environment
Eastern Canada – May 1-4, 2017 (St. John's, Newfoundland and Labrador, Summerside, Prince Edward Island, Saint John, New Brunswick and Halifax, Nova Scotia)	
Amec Foster Wheeler	Jonas Roberts, Climate Change Consultant, Environment and Infrastructures
CarbonCure Technologies	Jennifer Wagner, Vice-President, Sustainability
City of Summerside	His Worship Bill Martin, Mayor Norma McColeman, Deputy Mayor Greg Campbell, Councillor Brian McFeely, Councillor Gordie Whitlock, Councillor Bob Ashley, Chief Administrative Officer Greg Gaudet, Director of Municipal Services J.P. Desrosiers, Director of Community Services

	Rob Philpott, Director of Finance Mike Thusuka, Director of Economic Development Lorri Laughlin, Director of Communications Sam Arsenault, Waste Water Operations Supervisor Chad Fraser, Waste Water Treatment Operator
Dalhousie University	Dr. Richard Florizone, President Dr. Steven Mannell, Director, College of Sustainability Dr. Jeff Lamb, Deputy Chair, Dalhousie Facilities Management Dr. Ian Hill, Professor Dr. Mita Dasog, Assistant Professor Sara Daniels, Government Relations Advisor Emma Norton, Alumna Rochelle Weber, Student Jon-Paul Sun, Student Colby Deighton, Student
Emera	Chris Huskilson, President and Chief Executive Officer Robert Hanf, Executive Vice-President, Stakeholder Relations and Regulatory Affairs Lisa Merrithew, Vice-President, Communications and Corporate Affairs Sharon Scattolon, Facilities Manager Brad Stronach, HVAC Technician
Emera Newfoundland and Labrador	Norm Dimmell, P.Eng., Vice-President, Corporate Services
Fortis Inc.	Barry Perry, President and Chief Executive Officer Nora Duke, Executive Vice-President and Chief Human Resource Officer Gary Smith, President, Newfoundland Power

	Karen McCarthy, Director, Communications and Corporate Affairs Paul Fitzpatrick, Director, Regulatory and Compliance
Government of Newfoundland and Labrador	Walter Parsons, P.Eng., Assistant Deputy Minister, Energy Perry Canning, Assistant Deputy Minister, Mines
Irving Oil	Jeff Matthews, Chief Business Development Officer Graham Little, Government Relations Specialist James Walsh, Manager, Government Relations
J.D. Irving	Mary Keith, Vice-President, Communications Mark Mosher, Vice-President, Pulp & Paper Dion Hanrahan, Vice-President, Industrial Business Development Chris MacDonald, Director, Government Relations
McInnes Cooper	J. Alex Templeton, Associate
Nalcor	Gilbert Bennet, Executive Vice-President, Power Development Mark King, Stakeholder Relations and Communications Gayle St. Croix, Communications Consultant
Narl Refining LP	Tim Derksen, Management Program
NB Power	Keith Cronkite, Senior Vice-President Business, Development and Strategic Planning Brett Plummer, Vice-President Nuclear and Chief Nuclear Officer Robert Scott, Director, Government Relations Kathleen Duguay, Manager, Community Affairs and Nuclear Regulatory Protocol
Newfoundland and Labrador Environmental Industry Association	Kieran Hanley, Executive Director

NS Power	Karen Hutt, President and Chief Executive Officer Sasha Irving, Vice-President Corporate Affairs and Stakeholder Relations
Prince Edward Island Climate Change Secretariat	Todd Dupuis, Executive Director
Prince Edward Island Energy Corporation	Heather MacLeod, Manager, Energy Assets
St. John's Board of Trade	Dorothy M. Keating, Chair Nancy Healey, Chief Executive Officer Rhonda Tulk-Lane, Policy and Advocacy Specialist
Transportation, Infrastructure and Energy Efficiency - Prince Edward Island	Mike Proud, Manager, Office of Energy Efficiency
Trout River Homes Inc.	Terry and Natalie Perry, Owners Ralph and Beth Peters, House Owners
University of Prince Edward Island's Climate Lab	Dr. Adam Fenech, Director Hope Parnham, PhD Student
University of Prince Edward Island	Dr. Robert Gilmour, Vice-President Academic and Research

[1] Natural Resources Canada, *Energy Fact Book 2016-2017*.

[2] Government of Canada, Greenhouse gas sources and sinks: executive summary.

[3] United States Global Change Research Program (USGCRP), Climate Science Report: Fourth National Climate Assessment, Volume I, 2017.

[4] Ibid.

[5] United Nations, Intergovernmental Panel on Climate Change, Climate Change 2014: Impacts, Adaptation, and Vulnerability.

[6] Government of Canada, Clean growth and climate change working group reports, Working Group on Adaptation and Climate Resilience.

[7] Ibid.

[8] Figures are adjusted to 2016 dollars. Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 2 November, 2017 (Craig Stewart, Vice-President, Federal Affairs, Insurance Bureau of Canada).

[9] United Nations Framework Convention on Climate Change, The Paris Agreement.

[10] United States Climate Alliance, States United For Climate Action; America's Pledge, About.

[11] International Energy Agency, World Energy Outlook 2016 –Executive Summary.

[12] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 10 May, 2016 (Mike Cleland, Senior Fellow, University of Ottawa, as an individual).

[13] The Conference Board of Canada, The Cost of a Cleaner Future: Examining the Economic Impacts of Reducing GHG Emissions, 6 September, 2017.

[14] Government of Canada, Canada's Mid-Century Long-Term-Greenhouse Gas Development Strategy, 2016.

[15] Environment and Climate Change Canada, Canada's Seventh National Communication on Climate Change and Third Biennial Report—Actions to meet commitments under the United Nations Framework Convention on Climate Change, Page 9.

[16] Government of Canada, Global warming potentials.

[17] Ibid.

[18] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 7 December, 2017 (Julie Gelfand, Commissioner of the Environment and Sustainable Development, Office of the Auditor General of Canada).

[19] Government of Canada, Canada's Mid-Century Long-Term-Greenhouse Gas Development Strategy, 2016.

[20] The World Bank, Data, CO2 emissions (metric tons per capita).

[21] Environment and Climate Change Canada, Global Greenhouse Gas Emissions, figure is based on 2013 global emissions.

[22] Ibid.

[23] Government of Canada, Clean growth and climate change working group reports, Working Group on Clean Technology, Innovation and Jobs.

[24] International Energy Agency, World Energy Outlook 2016; and from International Energy Agency and International Renewable Energy Agency, Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System.

[25] National Energy Board, *Canada's Energy Future 2016: Update - Energy Supply and Demand Projections to 2040*, 2016.

[26] International Energy Agency, World Energy Outlook 2017.

[27] Petroleum Services Association of Canada, *Products Made from Oil & Gas (Part 1)* and Canadian Energy Pipelines Association, *6 ways your life would be different without oil and gas*, About Pipelines Blog, 10 December 2014.

[28] Petroleum Services Association of Canada, Products Made from Oil & Gas (Part 1).

[29] International Energy Agency, FAQs, Oil, and International Energy Agency, Key World Energy Statistics 2017.

[30] Canadian Association of Petroleum Producers, The Petroleum Value Chain: from crude oil to useful products.

[31] Natural Resources Canada, *Energy Fact Book 2016-2017*.

[32] Ibid.

[33] Ibid.
[34] Ibid.
[35] National Energy Board, Natural Gas, National Energy Board, 2016 Natural Gas Exports and Imports Summary.
[36] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (John Zhou, Vice President, Clean Energy, Alberta Innovates).
[37] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 28 February, 2017 (Mark A. Salkeld, President and Chief Executive Officer, Petroleum Services Association of Canada).
[38] Natural Resources Canada, *Energy Fact Book 2016-2017*.
[39] National Energy Board, *Canada's Energy Future 2016: Update - Energy Supply and Demand Projections to 2040*, 2016.
[40] Ibid.
[41] Ibid.
[42] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (John Zhou, Vice President, Clean Energy, Alberta Innovates).
[43] Alberta Energy Regulator, *Transportation and Facilities*.
[44] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (John Zhou, Vice President, Clean Energy, Alberta Innovates).
[45] Natural Resource Canada, 2017 Energy Fact Book, Alberta Energy, Facts and Statistics, *Environmental Protection and Enhancement Act*, RSA 2000, c E-12, and Conservation and Reclamation Regulation, Alta Reg 115/1993, Alberta Energy Regulator, Directive 085: Fluid Tailings Management for Oil Sands Mining Projects (October 12, 2017), replacing Directive 074: Tailings Performance Criteria and Requirements for Oil Sands Mining Schemes (2009).
[46] Natural Resources Canada, *Energy Fact Book 2016-2017*.
[47] Ibid.
[48] Fortis BC, Natural Gas, Tilbury LNG Facility.
[49] National Energy Board, *Canada's Energy Future 2016: Update - Energy Supply and Demand Projections to 2040*, 2016.
[50] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 12 April, 2016 (Jim Fox, Vice President, Integrated Energy Information and Analysis, National Energy Board).
[51] National Energy Board, *Canada's Energy Future 2016: Update - Energy Supply and Demand Projections to 2040*, 2016.
[52] National Energy Board, *Canada's Energy Future 2016: Update - Energy Supply and Demand Projections to 2040*, 2016.
[53] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 12 April, 2016 (Jim Fox, Vice President, Integrated Energy Information and Analysis, National Energy Board).
[54] National Energy Board, *Canada's Energy Future 2016: Update - Energy Supply and Demand Projections to 2040*, 2016.
[55] Environment and Climate Change Canada, "National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada," ***Part 1***, 2017.
[56] Environment and Climate Change Canada, "National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada," ***Annexes***, *Table A101*, 2017.
[57]Ibid.
[58] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 6 December, 2016 (Richard Sendall, Chairman, In Situ Oil Sands Alliance).

[59] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (Leah Lawrence, President and Chief Executive Officer, Sustainable Development Technology Canada); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (John Zhou, Vice President, Clean Energy, Alberta Innovates); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 June, 2017 (Robert Cadigan, President and Chief Executive Officer, Newfoundland and Labrador Oil & Gas Industries Association); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 6 December, 2016 (Richard Sendall, Chairman, In Situ Oil Sands Alliance).
[60] Environment and Climate Change Canada, "National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada," *Part 1*, 2017.
[61] Ibid.
[62] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 6 December, 2016 (Richard Sendall, Chairman, In Situ Oil Sands Alliance); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (John Zhou, Vice President, Clean Energy, Alberta Innovates).
[63] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 June, 2017 (Robert Cadigan, President and Chief Executive Officer, Newfoundland and Labrador Oil & Gas Industries Association).
[64] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 June, 2017 (Robert Cadigan, President and Chief Executive Officer, Newfoundland and Labrador Oil & Gas Industries Association).
[65] Environment and Climate Change Canada, "National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada," *Part 1*, 2017.
[66] Ibid.
[67] Ibid.
[68] Ibid.
[69] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 10 May, 2016 (Andrew Leach, Associate Professor, Alberta School of Business, University of Alberta, as an individual).
[70] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 December, 2016 (Mark Jaccard, Professor, Simon Fraser University).
[71] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 June, 2017 (Robert Cadigan, President and Chief Executive Officer, Newfoundland and Labrador Oil & Gas Industries Association).
[72] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 30 March, 2017 (Chris Ragan, Chair, Canada's Ecofiscal Commission).
[73] Government of Canada, Clean Growth and Climate Change Working Group Report, Specified Mitigation Opportunities Working Group, November 2016.
[74] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 5 October, 2017 (David Keane, President and Chief Executive Office, BC LNG Alliance).
[75] Government of Canada, Technical paper: federal carbon pricing backstop.
[76] The federal government plans to introduce new legislation and regulations to implement its carbon pricing system.
[77] Government of Canada, Output-based pricing system regulatory framework, Backgrounder.
[78] Government of Canada, Clean growth and climate change working group reports, Working Group on Carbon Pricing Mechanisms.
[79] Ibid.
[80] Canada's Ecofiscal Commission, Explaining Output-Based Allocation (OBAs).
[81] Government of Canada, Government of Canada releases further details on federal carbon-pollution pricing system, New Release, 15 January, 2018.
[82] Government of Canada, Technical paper: federal carbon pricing backstop.

[83] Government of Canada, Ministers McKenna and Morneau outline next steps in pricing carbon pollution, News Release, 20 September, 2017.
[84] Government of Canada, Government of Canada releases further details on federal carbon-pollution pricing system, New Release, 15 January, 2018.
[85] Manitoba, Manitoba's Made-in-Manitoba Climate and Green Plan.
[86] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 16 February, 2017 (Jennifer Winter, Assistant Professor, School of Public Policy, University of Calgary, as an individual).
[87] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 13 December , 2016 (Trevor McLeod, Director of the Centre for Natural Resources Policy, Canada West Foundation).
[88] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 29 November, 2016 (Benjamin Dachis, Associate Director, Research, C.D. Howe Institute).
[89] Ibid.
[90] Ibid.
[91] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 6 December, 2016 (Richard Sendall, Chairman, In Situ Oil Sands Alliance).
[92] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 11 May, 2017 (Aad van Bohemen, Head of Energy Policy and Security Division, International Energy Agency).
[93] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 December, 2016 (Mark Jaccard, Professor, Simon Fraser University, as an individual).
[94] Ibid.
[95] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 28 February, 2017 (Mark A. Salkeld, President and Chief Executive Officer, Petroleum Services Association of Canada).
[96] Ibid.
[97] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 30 March, 2017 (Chris Ragan, Chair, Canada's Ecofiscal Commission).
[98] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 6 December, 2016 (Eddy Isaacs, Scientific Advisory Committee Member, Council of Canadian Academies).
[99] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 29 November, 2016 (Benjamin Dachis, Associate Director, Research, C.D. Howe Institute).
[100] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 30 March, 2017 (Chris Ragan, Chair, Canada's Ecofiscal Commission).
[101] OECD, Environmental policy tools and evaluation, Environmental taxation.
[102] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 5 October, 2017 (David Keane, President and Chief Executive Office, BC LNG Alliance).
[103] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 June, 2017 (Terry Abel, Executive Vice-President, Canadian Association of Petroleum Producers).
[104] Office of the Auditor General of Canada, 2017 Spring Reports of the Auditor General of Canada, Report 7 –Fossil Fuel Subsidies.
[105] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 7 December, 2017 (Julie Gelfand, Commissioner of the Environment and Sustainable Development, Office of the Auditor General of Canada).
[106] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 30 March, 2017 (Chris Ragan, Chair, Canada's Ecofiscal Commission).
[107] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 December, 2016 (Mark Jaccard, Professor, Simon Fraser University, as an individual).

[108] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 16 February, 2017 (Jennifer Winter, Assistant Professor, School of Public Policy, University of Calgary, as an individual).
[109] Ibid.
[110] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 30 March, 2017 (Chris Ragan, Chair, Canada's Ecofiscal Commission).
[111] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 2 February, 2017 (Steve MacDonald, Chief Executive Officer, Emissions Reduction Alberta).
[112] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 11 May, 2017 (Aad van Bohemen, Head of Energy Policy and Security Division, International Energy Agency); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 16 February, 2017 (Jennifer Winter, Assistant Professor, School of Public Policy, University of Calgary, as an individual); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 30 March, 2017 (Chris Ragan, Chair, Canada's Ecofiscal Commission); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 29 November, 2016 (Benjamin Dachis, Associate Director, Research, C.D. Howe Institute).
[113] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 13 December , 2016 (Trevor McLeod, Director of the Centre for Natural Resources Policy, Canada West Foundation).
[114] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 30 March, 2017 (Chris Ragan, Chair, Canada's Ecofiscal Commission).
[115] Government of Canada, Clean growth and climate change working group report, Specified Mitigation Opportunities Working Group.
[116] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 December, 2016 (Mark Jaccard, Professor, Simon Fraser University, as an individual).
[117] Ibid.
[118] Ibid.
[119] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 6 December, 2016 (Eric M. Meslin, President and Chief Executive Officer, Council of Canadian Academies).
[120] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 December, 2016 (Mark Jaccard, Professor, Simon Fraser University, as an individual).
[121] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 June, 2017 (Robert Cadigan, President and Chief Executive Officer, Newfoundland and Labrador Oil & Gas Industries Association).
[122] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 June, 2017 (Terry Abel, Executive Vice-President, Canadian Association of Petroleum Producers).
[123] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 2 February, 2017 (Steve MacDonald, Chief Executive Officer, Emissions Reduction Alberta).
[124] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 12 April, 2017 (Timothy M. Egan, President and Chief Executive Officer, Canadian Gas Association).
[125] Ibid.
[126] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 11 May, 2017 (Aad van Bohemen, Head of Energy Policy and Security Division, International Energy Agency).
[127] Government of Canada, Technical Backgrounder: Proposed Federal Methane Regulations for the Oil and Gas Sector.
[128] Ibid.

[129] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 June, 2017 (Terry Abel, Executive Vice-President, Canadian Association of Petroleum Producers).
[130] Prime Minister of Canada, U.S.-Canada Joint Statement on Climate, Energy, and Arctic Leadership.
[131] United States Federal Register, Waste Prevention, Production Subject to Royalties and Resource Conservation; Delay and Suspension of Certain Requirements.
[132] Government of Canada, Technical Backgrounder: Proposed Federal Methane Regulations for the Oil and Gas Sector.
[133] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 6 April, 2017 (John Moffet, Acting Associate Assistant Deputy Minister, Environment and Climate Change Canada).
[134] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (John Zhou, Vice President, Clean Energy, Alberta Innovates).
[135] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 2 February, 2017 (Steve MacDonald, Chief Executive Officer, Emissions Reduction Alberta).
[136] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (John Zhou, Vice President, Clean Energy, Alberta Innovates).
[137] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (Leah Lawrence, President and Chief Executive Officer, Sustainable Development Technology Canada).
[138] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 2 February, 2017 (Qi Liu, Scientific Director, Institute for Oil Sands Innovation).
[139] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 6 December, 2016 (Eddy Isaacs, Scientific Advisory Committee Member, Council of Canadian Academies).
[140] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 2 February, 2017 (Steve MacDonald, Chief Executive Officer, Emissions Reduction Alberta).
[141] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 1 December, 2016 (Soheil Asgarpour, President, PTAC Petroleum Technology Alliance Canada).
[142] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 6 December, 2016 (Eric M. Meslin, President and Chief Executive Officer, Council of Canadian Academies).
[143] MEG Energy, *Non-Condensable Gas Co-Injection*.
[144] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 1 December, 2016 (Soheil Asgarpour, President, PTAC Petroleum Technology Alliance Canada).
[145] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 1 December, 2016 (Soheil Asgarpour, President, PTAC Petroleum Technology Alliance Canada); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 28 February, 2017 (Mark A. Salkeld, President and Chief Executive Officer, Petroleum Services Association of Canada).
[146] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 11 May, 2017 (Aad van Bohemen, Head of Energy Policy and Security Division, International Energy Agency).
[147] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (Leah Lawrence, President and Chief Executive Officer, Sustainable Development Technology Canada); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 2 February, 2017 (Qi Liu, Scientific Director, Institute for Oil Sands Innovation); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (John Zhou, Vice President, Clean Energy, Alberta Innovates).

[148] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 2 February, 2017 (Steve MacDonald, Chief Executive Officer, Emissions Reduction Alberta).
[149] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (Leah Lawrence, President and Chief Executive Officer, Sustainable Development Technology Canada); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (John Zhou, Vice President, Clean Energy, Alberta Innovates); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 2 February, 2017 (Qi Liu, Scientific Director, Institute for Oil Sands Innovation).
[150] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (John Zhou, Vice President, Clean Energy, Alberta Innovates).
[151] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 1 December, 2016 (Soheil Asgarpour, President, PTAC Petroleum Technology Alliance Canada).
[152] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (John Zhou, Vice President, Clean Energy, Alberta Innovates).
[153] Ibid.
[154] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 6 December, 2016 (Richard Sendall, Chairman, In Situ Oil Sands Alliance).
[155] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 1 December, 2016 (Soheil Asgarpour, President, PTAC Petroleum Technology Alliance Canada); see for example: Zhiwri Ma, Juliana Y. Leung and Stefan Zanon, "Practical Data Mining and Artificial Neural Network Modeling for Steam-Assisted Gravity Drainage Production Analysis," *Journal of Energy Resources Technology*, 139(3), 8 February 2017.
[156] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 1 December, 2016 (Soheil Asgarpour, President, PTAC Petroleum Technology Alliance Canada); see for example: Natural Resources Canada, *Enhancements to an Online Steam Analyser for Thermally Enhanced Heavy Oil Recovery*, September 2017.
[157] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 1 December, 2016 (Soheil Asgarpour, President, PTAC Petroleum Technology Alliance Canada).
[158] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 1 December, 2016 (Soheil Asgarpour, President, PTAC Petroleum Technology Alliance Canada); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (John Zhou, Vice President, Clean Energy, Alberta Innovates).
[159] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 1 December, 2016 (Soheil Asgarpour, President, PTAC Petroleum Technology Alliance Canada); see Pierre Meulien, "Genomics and Energy: Harnessing the Power of Biology to Develop Clean and Sustainable Systems," *Policy: Canadian Politics and Public Policy*, September/October 2014.
[160] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 1 December, 2016 (Soheil Asgarpour, President, PTAC Petroleum Technology Alliance Canada).
[161] Written submission presented to the Committee by John Zhou, Alberta Innovates, *Submission to the Standing Committee*, 24 November 2016.
[162] Natural Resources Canada, *Energy Fact Book 2016-2017*.
[163] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (Leah Lawrence, President and Chief Executive Officer, Sustainable Development Technology Canada); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 1 December, 2016 (Soheil Asgarpour, President, PTAC Petroleum Technology Alliance Canada); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 2 February, 2017 (Steve MacDonald, Chief Executive Officer, Emissions Reduction Alberta); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 June, 2017 (Terry Abel, Executive Vice-President, Canadian Association of Petroleum Producers).

[164] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 2 February, 2017 (Steve MacDonald, Chief Executive Officer, Emissions Reduction Alberta); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 1 December, 2016 (Soheil Asgarpour, President, PTAC Petroleum Technology Alliance Canada).
[165] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 June, 2017 (Terry Abel, Executive Vice-President, Canadian Association of Petroleum Producers).
[166] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 1 December, 2016 (Soheil Asgarpour, President, PTAC Petroleum Technology Alliance Canada).
[167] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (Leah Lawrence, President and Chief Executive Officer, Sustainable Development Technology Canada).
[168] Ibid.
[169] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 2 February, 2017 (Steve MacDonald, Chief Executive Officer, Emissions Reduction Alberta).
[170] Ibid.
[171] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 28 February, 2017 (Mark A. Salkeld, President and Chief Executive Officer, Petroleum Services Association of Canada).
[172] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 December, 2016 (Mark Jaccard, Professor, Simon Fraser University, as an individual).
[173] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 June, 2017 (Terry Abel, Executive Vice-President, Canadian Association of Petroleum Producers).
[174] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 2 February, 2017 (Steve MacDonald, Chief Executive Officer, Emissions Reduction Alberta).
[175] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 2 February, 2017 (Steve MacDonald, Chief Executive Officer, Emissions Reduction Alberta); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (Leah Lawrence, President and Chief Executive Officer, Sustainable Development Technology Canada); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 1 December, 2016 (Soheil Asgarpour, President, PTAC Petroleum Technology Alliance Canada); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 6 December, 2016 (Richard Sendall, Chairman, In Situ Oil Sands Alliance); Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 June, 2017 (Terry Abel, Executive Vice-President, Canadian Association of Petroleum Producers).
[176] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 1 December, 2016 (Soheil Asgarpour, President, PTAC Petroleum Technology Alliance Canada).
[177] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 24 November, 2016 (Leah Lawrence, President and Chief Executive Officer, Sustainable Development Technology Canada).
[178] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 8 December, 2016 (Mark Jaccard, Professor, Simon Fraser University, as an individual).

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